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ROYAL GEOGRAPHICAL SOCIETY

HINTS TO TRAVELLERS.

SEVENTH EDITION.

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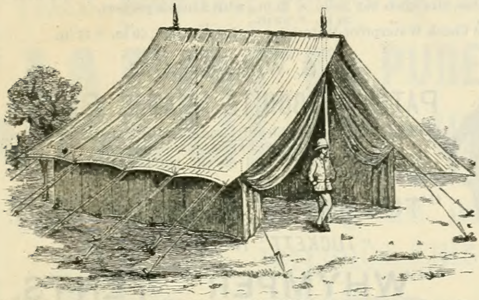

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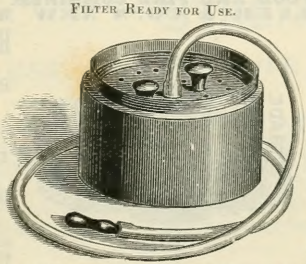

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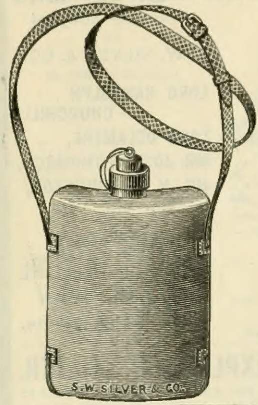

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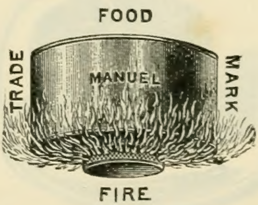

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HINTS TO TRAVELLERS

SCIENTIFIC AND GENERAL

EDITED FOR THE

Council of the Royal Geographical Society

BY

DOUGLAS W. FRESHFIELD, Hon. Sec. R.G.S.

AND

CAPTAIN W. J. L. WHARTON, R.N., F.R.S.,

Hydrographer to the Admiralty.

SEVENTH EDITION

REVISED AND ENLARGED

LONDON:

THE ROYAL GEOGRAPHICAL SOCIETY,

1, SAVILE ROW, W.

AND AT ALL BOOKSELLERS'.

1893.

Price Eight Shillings; to Fellows, at the Office of the Society, Five Shillings.

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SECTIONS AND AUTHORS.

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PREFACE TO SIXTH EDITION.

In issuing to the Fellows of the Royal Geographical Society and the public the sixth edition of *Hints to Travellers* it seems desirable to give a brief historical sketch of the various changes the work has gone through before it reached its present form.

As long ago as 1854 the Council of the Society, in consequence of the frequent questions addressed to them by intending travellers, requested the late Admiral Fitzroy and Lieutenant Raper, R.N., to consider what instrumental outfit might best be recommended to explorers. Their report, together with suggestions submitted to them by Admirals Smyth and Beechey, Colonel Sykes and Mr. Francis Galton, was printed in vol. xxiv. of the Journal of the Society, and separately circulated in pamphlet form under the title of 'Hints to Travellers.'

The exhaustion of this first edition led, in 1864, to the revision and enlargement of the original work by a Committee of Council, consisting of Sir George Back, Admiral Collinson and Mr. Francis Galton. Their 'Hints' were prefaced by the remark that they were addressed to a person who, proposing to explore a wild country, asks what astronomical and other scientific outfit he ought to take with him, and what observations he may attempt with a prospect of obtaining accurate results. Hints on Photography by Dr. Pole, and on the Collection of Objects in Natural History by Mr. Bates, were added.

The success of this volume resulted in the publication, in 1871, of a third edition under the same editorship. This edition was followed in 1878 by the fourth, published under the sole editorship of Mr. F. Galton, and in a new form more convenient for pocket use.

In preparing the fifth edition the Council, anxious to increase the usefulness of the volume, and to make it meet the, in some ways, higher requirements of a new generation of young travellers, many of whom had received scientific instruction in the Society's office before leaving England, appointed an Editorial Sub-Committee, consisting of Colonel H. H. Godwin Austen, Mr. J. K. Laughton, and Mr. Douglas W. Freshfield, to remodel the 'Hints.'

The first object of those charged with the direction of this edition was to furnish such help as might be possible within the compass of a convenient pocket-book to the intelligent explorer who, in the hope of obtaining from his travels valuable geographical results, has been at some pains to acquaint himself with the use of instruments. The Hints on Surveying, the principal portion of the work, were placed in the hands of Mr. Coles, late R.N., the Society's Map-Curator and Instructor in Practical Astronomy and Surveying.

The Hints on Collections in Natural History were expanded, and Hints on how and what to observe in other sciences, Geology and Anthropology, added by Mr. W. T. Blanford and Mr. E. B. Tylor respectively. The section on Photography was re-written by Mr. W. F. Donkin, who had, in the High Alps, had exceptional experience in taking photographs under circumstances of great difficulty, both as to transport and exposure. Since the success of every journey depends primarily on the health and suitable equipment of the members of the expedition, the Editors decided further to enlarge the scope of the work by supplying Hints on Medical Treatment and Precautions, and on General Outfit. The former, drawn up by Surgeon-Major Dobson, have been found of great value.

This fifth edition is now exhausted. The changes and additions made in it having met with general approval, the present Editors have not attempted to make any material alteration in the character of the book. It has received at their hands such correction as time and the progress of science and discovery render needful, and such additions as experience suggests may be of use. The various sections have been revised, and enlarged in most cases, by their authors. The hints on Meteorology have been re-written by Mr. H. F. Blanford. Captain Abney has brought up to date the late Mr. W. F. Donkin's notes on Photography, and Mr. J. S. Keltie has supplied new hints on Commercial Geography. An index has been added.

In a work of this character omissions must of necessity be discovered. In order to reduce their number and importance as far as possible, it has throughout been the aim of the Editors not only to intrust each chapter to a competent hand, but also to provide for its being read and revised before publication by high independent authorities in the same branch of knowledge. This course could not have been carried out without the cordial assent and co-operation of their responsible contributors, to whom, as well as to the many gentlemen who have given the benefit of their advice, the Council desire to return their grateful acknowledgments.

Any corrections or additions which may suggest themselves to readers should be communicated to the Secretary of the Society, 1, Savile Row, W., for the use of the Editors of the next Edition.

DOUGLAS W. FRESHFIELD.

June, 1889. W. J. L. WHARTON.

PREFACE TO SEVENTH EDITION.

In the present edition important additions and corrections have been made, but no material alteration has been made in the general arrangement. The various sections have been revised and brought up to date, and the Medical Hints have been re-written.

DOUGLAS W. FRESHFIELD.
W. J. L. WHARTON.

HINTS TO TRAVELLERS.

I.

PRELIMINARY HINTS.

By Douglas W. Freshfield, Hon. Sec. R.G.S.,
President of the Alpine Club.

This work will come into the hands of very different readers. In the first place it will undergo the criticism of the small body of what may be called "professional" travellers, men trained in at least the elements of surveying, practised in general observation, and experienced in the shifts of travel. By them, it is hoped, it may be accepted as a handy, and at times a suggestive pocket-book. But travellers such as these now form only a small proportion of the Englishmen and Englishwomen who, on business or pleasure, yearly extend their wanderings over the globe. One of the results of the rapid multiplication of lines of ocean steamers and of railways in distant seas and far-off countries has been to make it easy for men of comparatively brief leisure to undertake a share in exploration in the course of a vacation tour. The goal of ten years ago has become a starting-point; Merv has a railway station and several inns; excursion steamers run—or will shortly run—to Alaska and Mount St. Elias. India has become commonplace, and Members of Parliament spend their holidays in Siberia, Brazil, Korea, or the Antipodes. The vacation travellers, or tourists, who are tempted by modern facilities into imperfectly-known regions are numerous, and their opportunities for collecting valuable information are great, while their power of profiting by them is as a rule far from commensurate.

The children's story of "Eyes and No Eyes" is constantly being exemplified in the recent literature of travel. It would be extravagant indeed to expect all travellers to take up scientific surveyor's work,

however desirable it may be to increase the number of those who do so. Again, few Englishmen would have the patience to emulate the native Indian surveyor who measures the distances traversed over many hundred miles by ceaselessly counting his own paces. But topography and géodesy are but a part, even if the foundation, of modern geography. It is a loss, both to himself and to others, when a traveller does not observe, or fails to take notes of, the objects and the people he meets with; when he brings back no fresh facts as to topography, natural history, climate, customs, and antiquities; when he uses neither the pencil nor the camera to record the scenery, the buildings, or the people he has met with in his journey. The aim of this volume is to assist all travellers to make their travels more pleasant to themselves and more profitable to others by increasing at once their interests and their means of observation. *Non omnia possumus omnes!* Each will take, doubtless, his own special line. Yet it may be well to point out that there is no one more in need of warning and advice than the specialist or "scientist" who confines himself to one branch of knowledge. He is apt not only to miss opportunities in other branches, but he frequently impairs the soundness of his observations in his own subject by failing to take into account, accurately and intelligently, natural agencies or phenomena which interact with those that he especially studies. There is yet another class for whom this work is intended, those residents abroad whom duty compels to spend large portions of their lives in remote localities, and who have, therefore, the best opportunities for collecting and presenting complete and accurate information concerning distant regions. These 'Hints' have been discovered by Lieutenant Younghusband in the hands of a Russian Consul-General in Central Asia! Certain additions, with a particular view to the advantage of such far-off residents, have been made to the Medical Hints, the value of which has been borne witness to by many of the travellers who have used recent editions of this work.

The traveller, as soon as he has resolved where he means to go, should read the best books on the country, and decide which, if any, it is worth his while to take with him, and make extracts for his own use from others. Still more important is it for him to study the best maps, and with these it is indispensable that he should provide himself, mounted for use; a map that cannot be kept in the pocket is of little service. If

he is residing in England, the traveller will find the needful books and maps at the Royal Geographical Society, the officials of which will give him any information in their power, and put him in communication with those who can give more. He will do well also to consider the question of language, and, if possible, to learn something beforehand of any that is likely to be specially useful to him; at any rate, to provide himself with a dictionary and phrase-book, where such exist. If he is no draughtsman—indeed in any case—he can, and ought to, take some lessons in photography, which, though an art in the hands of only a few, is a tool of the utmost value in most branches of discovery for the many. Such lessons can be procured through the Royal Geographical Society's Scientific Instructor. The Society's Secretary, Mr. Keltie, is also instructed to arrange lectures in botany and geology for intending travellers.*

The would-be explorer should, by all means, after a sufficient reference to the best sources of information, form a detailed scheme of what he intends, or rather hopes, to do. How far this scheme should be adhered to is a question to be governed by circumstances and personal advice. Local advice should be given its due weight, taking into account the individual character, and official or other particular bias of the informant, and also bearing in mind, on the one hand, that where danger from inhabitants is concerned, the conditions of travel are apt to vary from year to year, and that the latest news is generally the surest; on the

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* The following is the advertisement issued by the Society with regard to the terms of these lessons (1889).

Arrangements have been made for the instruction of intending travellers in the following subjects:—

1. Surveying and Mapping, including the fixing of positions by Astronomical observations. By Mr. John Coles, Map Curator of the Society.
2. Geology, including practical training in the field. By Mr. W. Topley, of the Geological Survey; President of the Geologists' Association.
3. Botany. Applications should be made to the Director, Royal Gardens, Kew.
4. Photography. By Mr. John Thomson, Author of 'Photographic Illustrations of China and its People,' and other works.

The lessons are given on days and at hours arranged between the Instructor and the pupil. The fee to pupils is, for each lesson of an hour, 2*s.* 6*d.* Tickets for the lessons must be previously procured at the Offices of the Society.

other, that residents are apt to over-estimate obstacles they have never themselves faced. The unknown, in mountains and elsewhere, is often the impossible even for educated Englishmen—much more is it so for the native inhabitants.

In the selection of his field the professional traveller who seeks wholly new ground need, as yet, be at no loss for choice, even outside the Arctic and Antarctic regions. The interior of New Guinea is still almost virgin to Europeans; several of the East Indian Islands, particularly Borneo and Formosa, large portions of Tibet, and the native states on the northern frontier of India and Upper Burmah, present many purely topographical problems. Africa is still very far from being exhausted, if the mysteries to be solved in it are gradually being narrowed. South and Central America seem at last to attract their fair share of enterprise; and the ranges on the Pacific coast of North America are, from the scale of their glacial phenomena, certain soon to be studied in detail. But the old conception of geography which looked on it as pure topography, as equivalent to surveying and map-construction, is fast dying out, and travellers, as well as geographers, are becoming familiar with the idea that their business is to furnish a picture of the earth's surface as it is, and in relation to its inhabitants. To this knowledge, as set forth in such a work as M. Reclus's 'Géographie Universelle,' an acquaintance with the topography of a country is only a preliminary. It may seem a paradox, yet it is true, that there is hardly a country in Europe the materials for the geography of which are complete. In England itself, to give a single instance, we do not yet know the depths of our inland waters. Large tracts of the Alps and the Pyrenees were within the last twenty-five years, mapped for the first time with any approach to accuracy by private and individual energy. The Balkan Peninsula is far from being exactly described. A little further afield in Morocco, Asia Minor, the Western Caucasus, Syria east of the Jordan, in the easily-accessible western portions of Northern America—in short, in regions within a fortnight of London, there is still room for any number of intelligent observers.

Next to the choice of the field for travel comes another primary matter on which hints are hardly likely, perhaps, to be serviceable, yet, which is the most important of all—the choice of a companion. Those who have never travelled at all together will always, before entering on

any prolonged partnership, be wise to test their sympathy or powers of mutual accommodation, in some short excursion. Of course diversity of studies will lead to greater richness in results. A first-rate photographer—a first-rate specialist of any kind—is apt to get absorbed in his work; it is everything that his companion should be industrious with his note-book, and handy in camp. A botanist, or an entomologist, is very apt to see nothing more than a few yards distant; a mountaineer to overlook any feature less than two miles high! Where tastes are diverse each will learn from his companion, and the common result will be enriched.

A few commonplaces, drawn chiefly from the writer's own limited experience, may perhaps be added usefully here. In all dealings with camp-servants and natives be first of all patient, next just and firm, dealing praise and blame alike sparingly, but heartily. Never lose your temper—except on purpose, and avoid banter. When you have to communicate through an interpreter, endeavour to be present yourself at all important discussions. Arrange for your transport for as long periods as convenient, and pay whenever possible by distance, and not by time, if you want to get on. Do not let your visit be an expense, but rather a source of profit, in some way or other, to your hosts. The present you intend to give on leaving may be judiciously shown and hinted at beforehand; it will increase the attention paid you, and be more effective than if kept in reserve as a surprise.

Make it a rule to start as early in the day as possible. In many climates clouds obscure the view, or the heat is intolerable in the afternoon. And it is an advantage when camping to have plenty of daylight after arrival.

Remember that the first and best instruments are the traveller's own eyes. Use them constantly, and record your observations on the spot, keeping for the purpose a note-book with numbered pages and a map (where the latter is procurable) always at hand in a buttoned pocket. The more little rough sketches, outlines, sketch-maps you introduce into your note-book the better. Put down, as they occur, all important objects; streams, their volume, colour; mountain ranges, their character and apparent structure and glaciation, the colour and forms of the landscape, prevalent winds, climate. Note all *changes* in the physical aspect of the country, soil, rocks, vegetation, flora, and fauna; the limits of

tribes, their dwellings, places of worship, tombs, and particularly ancient cemeteries, domestic furniture, customs, antiquities, &c. In short, describe to yourself at the time all you see and learn in your diary.

I have purposely limited myself here to the most elementary suggestions. I do not, of course, assume that any traveller will be without at least a good watch, a compass, a thermometer, and an aneroid (an instrument which, *carefully worn* like a watch, from the commencement of the journey, I have found more satisfactory than have most travellers, and in which further improvements may be looked for). But I must not trespass here on the province of the Scientific Instructor. Readers will find all necessary information in the important section of this work which Mr. Coles, under the supervision of my co-editor, Captain Wharton, R.N., the Hydrographer to the Admiralty, and with the assistance of several distinguished survey officers, has very carefully revised.

General instructions as to linguistic collections will be found among the Hints on Anthropology. The traveller's business is to try and get a native name for everything he sees. But to ascertain correctly the native names for natural features, and even for villages, is often a very troublesome task, and the most grotesque blunders may easily be made. Pronunciation in a partially-understood tongue or dialect is imperfectly heard, and a little knowledge leads astray. Names are frequently given to districts rather than to individual hamlets. Streams are differently named in different parts of their course.

But it is with mountain ranges, and, above all, with individual summits, that the greatest difficulties arise. A summit, unless exceptionally conspicuous, has frequently no name apart from the chain or block to which it belongs, or the pass nearest it. A chain or block will get a name from the pasturage on its slope; or it will be called after the valley at its base; or, more frequently, from the valley on the other side reached by crossing it. In the latter case, it is obvious that it will probably have two names. As a rule a name given to a *massif*, or group, should be applied to its highest point. For that it is vertical, and not lateral, extension that differentiates mountains, that their essential feature is their height, and that their individuality resides in their highest point, are very modern refinements.

Whatever further hints my experience suggests may best be included in the chapters that follow. I will here only add a few words as to

the method and form to be adopted by the traveller in preparing the permanent record of his journey after its completion.

The traveller, immediately on his return, should write out from his notes a full diary. This done, let him lay it aside for a short time, and read afresh all he can find on his subject. He will then be ready to take up again his own manuscript, and, if he sees his way to make an interesting paper or volume, to come to the important decision whether he shall retain the narrative form, or arrange his material otherwise. Should he retain the narrative form—and it has many advantages—let him erase repetitions; enlarge on, or mass together, typical and instructive experiences; insert, where most convenient, condensed summaries of the results of his observations on special subjects, showing how and where they modify, or enlarge, the conclusions of his predecessors. The lecturer or author who furnishes a bare record of how he got over the ground, without pausing to give any definite picture of what he has seen and learnt, is the terror of geographical meetings, and his book is destined to comparative failure. His observations may serve as a basis for maps; he may have earned credit as an exact topographer; but as a geographer, in the higher sense of the word, he will have failed. Statistics, and details of topography and distances, most valuable in the study, should, as a rule, be omitted in reading a paper before a general audience, which requires definite pictures sufficiently filled in to be apprehended and remembered. If the traveller has to give many figures, or much technical information not necessary to the general reader, let him employ an appendix or footnotes. Finally let him attend himself to his maps and illustrations, and not forget a good index.

II.

HINTS ON OUTFIT.

INCLUDING NOTES ON WATER TRAVEL AND MOUNTAIN TRAVEL.

Compiled by Douglas W. Freshfield, *with the aid of* E. Whymper, J. Thomson, H. H. Johnston, J. Coles, *and others.*

Suggestions regarding a suitable outfit for a traveller must necessarily be of the most general character, as each traveller requires a special outfit according to the nature of his journey, its aims and duration, the number of persons composing the expedition, and the funds at command. An outfit which might be very complete and suitable for an Arctic journey or a very cold climate must obviously be unsuited for a journey in tropical countries, though it might contain some articles useful in all regions. And even where the conditions may not be so wholly dissimilar as in the cases mentioned, as, for example, in South America, Australia, and Central Africa, the traveller will in each country require many distinct articles, and find others superfluous. In all cases where special information is needed, the intending traveller will do well to apply to the officials of the Geographical Society, who, as a rule, are able to put him into communication with the best authorities of all—his last predecessors in the region he is about to visit. He may also obtain much useful general information from Mr. F. Galton's 'Art of Travel,' and Messrs. Lord and Baines's 'Shifts and Expedients of Camp Life.' For more detailed information as to particular branches of his outfit—*e.g.*, Scientific Instruments, Photographic Apparatus, Medicines, or the paraphernalia of a naturalist, he should also consult the chapters to which references are hereafter given, and the Report on Equipment, published (1892) by the Alpine Club, to which is appended a useful list of addresses of trade-firms. His next step will be to visit some great London outfitters—*e.g.*, Messrs. Silver & Co. of Bond Street, the Jaeger Company, Princes Street, Cavendish Square, who supply a special

mountain outfit, where he may see specimens of the goods that have been supplied to travellers, and of the inventions they have devised.

It is not advisable to lay down any absolute rule as to whether the traveller should complete his outfit at home or abroad. There may be some occasions on which it may be best to complete abroad. Customs duties in some countries, particularly Russia and the United States, have to be taken into account. But, inasmuch as far greater facilities of purchase and for packing are to be had at home, the reasons would have to be very weighty and exceptional which would render it desirable to complete abroad.

Travellers, again, in some regions require to carry much of their food with them, while in others they can obtain almost all necessary sustenance on the spot. In some countries there are considerable facilities for transport, and there is no need to reduce the baggage to very small dimensions; in others the difficulty of transport is amongst the greatest to be encountered. These various considerations must all be taken into account, and the leader of an exploring expedition will give the first proof of his fitness by showing, by judicious selection, that he appreciates the relative importance of particular articles.

In the arrangement and packing of the stores there are, again, considerable opportunities for the exercise of sound judgment.

On this subject some hints may be offered under four heads, viz.:—methodical arrangement, security, economy, and the catalogue.

1. *Methodical Arrangement.*—Articles likely to be in most frequent use should be packed together, care being taken not to bring articles likely to injure one another into close contact. Tins must be kept apart from anything breakable. Fragile articles (such as glass bottles) should be packed in small separate boxes or cases, so that, should they be broken, they may not leave a void which will cause all the contents of their case to jumble about. Chemicals and explosives should be kept separate from other things; and, before being packed, inquiry should be made as to regulations to which they will have to submit on ship-board, &c. If the goods have to undergo customs examination, the traveller must be present himself, or he risks the goods being disarranged and carelessly repacked, and the eatables extensively tested by tasting.

2. *Security* against (*a*) breakage, (*b*) damp, and (*c*) robbery should be studied whilst packing.

a. To guard against breakage, packages should be of reasonable dimensions. For an inland traveller 75 lbs. gross weight should be about the maximum of any single package. A horse or mule can take a (conveniently shaped) box of this weight on each side, and 50 to 60 lbs. between them on the top. Where goods are intended to be carried by porters, it is not recommended that any single package should weigh more than 56 lbs. Heavier packages will almost certainly have to submit to very rough treatment. Further security against breakage can be had by sub-division, that is to say, by packing boxes inside boxes, tins within tins, &c. Everything should be *tightly* packed, and all vacant spaces filled up. Oblong boxes travel best. The air-tight packages manufactured by Messrs. Silver & Co. are recommended, but for a prolonged journey require to be protected by outer wooden cases. On reaching the point beyond which goods must be carried over rough country on the backs of animals or men, such cases will conveniently be exchanged for saddle-bags made of strong waterproof material. Each pair of saddle-bags should be arranged with shoulder-straps for the use of porters. A few large bags of the sort known in Tyrol as *Rucksacks*—made of Willesden canvas, of which various approved sizes can be got at Silver's—are most convenient for the carriage of small packages, and when not in use are so light that they can easily be stowed away. It is obviously desirable that some of the packages should be capable of being kept under padlocks. Several canvas bags and several dozen linen bags are very useful for packing.

b. To guard against damp (on ship-board, in countries with heavy rains, passage of rivers, &c.), all perishable things should, where practicable, be enclosed in tin and soldered, *particular care being taken that everything is thoroughly dry before being soldered up*. It pays the traveller well to have his outer wooden cases made of the best deal, closely fitted, and varnished or double varnished to prevent absorption of moisture by the wood.

c. Closely-fitted, well-made cases afford great trouble to thieves, and gaping packages, with partly-exposed contents, invite robbery. Boxes which are *screwed* down are more secure than nailed boxes, as thieves are frequently not provided with screwdrivers. Use *brass* screws, if possible, for cases which have to be frequently opened and re-opened; iron screws, if used, should be tallowed before insertion; they will then unscrew more

easily. Articles of value should be kept out of sight as much as possible.

3. *Economy.*—It is false economy for the traveller to buy any but the best articles for his outfit, or to carry useless things. Many articles may be put to double uses, and economy can be effected by selecting such materials as can be most widely applied. For example, articles to be used as presents may also be put to use on the journey. There should be no waste space in the packages. Every interstice can be filled up with articles which may be turned to account. For the finishing touches tow, cotton-wool, and paper, crumpled into balls the size of walnuts, may be advantageously employed, as all these materials can be used for a diversity of purposes. If the traveller does not himself superintend the packing of his goods, he must not expect foresight in these small but important particulars.

4. *The Catalogue of Outfit.*—As each package is finished its contents should be carefully catalogued, and the package numbered distinctly on several sides, corresponding numbers to be entered in the catalogue. In the event of the contents of a box being varied and numerous, roughly classify them before entering. The traveller himself should carry the catalogue on his person, and, where there are a large number of packages and articles, it will be found of advantage to form a classified catalogue showing the disposition of the articles, as well as a numerical one showing the contents of each package.

The articles which go to make up a more or less complete outfit may be roughly classified under the following heads:—1, Provisions; 2, Clothing; 3, Instruments; 4, Stationery, note-books, books and maps; 5, Appliances for collecting; 6, Articles for presents or barter; 7, Camp equipments; 8, Medicines; and 9, Photographic Apparatus.

1. *Provisions.*—The following are good for all countries and all climates:—tea (in tins); preserved milk (Milkmaid Brand), or cocoa and milk (in tins); arrowroot; Liebig's extract (sold usually in jars, but will keep equally in well-soldered tins); preserved soup in tins; Bovril; Edwards' Desiccated soup; Silver's self-cooking soup tins (invaluable in any emergency when a fire is impossible); sardines (in tomato sauce); potted bloaters; Symington's pea-flour soup (excellent at low temperatures, and requiring only one minute's boiling); lemonade effervescing powder (will keep perfectly if soldered in tin); oatmeal and baking

powder; dried onions; eating raisins; chocolate in cakes; mustard, salt, pepper, and curry powder; marmalade in corked bottles; Chelsea table jelly; Moir's fresh herrings; and Erbswurst. Jam in ¼ lb. tins.

Kola-nut biscuits have marvellous effect in sustaining strength during exertion. They are to be had of M. Gaucher, St. Barnabé, Banlieu de Marseille, and cost 2 fr. 50 c. the kilogram.

Preserved meats can now be procured in nearly all civilised towns, and in most instances will keep for an almost unlimited length of time. When purchasing, all tins should be inspected, and *bulged or battered ones should be rejected.* A convex end indicates putrefaction inside. The best course is to purchase direct from general providers or makers of established reputations. A small box with screw-on lid for holding salt. Empty provision-tins are often highly appreciated as presents, and the larger can be utilised also for natural history specimens (birds and mammals); the smaller for shells, insects, &c.

2. *Clothing.*—Woollen goods are to be preferred for all countries and for all climates. Boots should be amply provided, and be got into wear before departure; they should be broad-soled, not too thick or heavy, and one pair at least large enough to admit of two pair of socks being worn. Double socks and easy boots are the best prevention against frost-bite or sore feet in long marches on rough ground. Porpoise hide is worth the extra cost. A supply of nails should be taken. An "ulster" coat, one or two sizes larger than a fit, will be found useful to sleep in. A stout mackintosh will keep all but the legs dry on a long march, and in temperate climates at least is very serviceable. In the tropics the light oil-skin coats now made will answer the same purpose. Travellers who have been in, or near, the districts to be visited, should always be consulted as to what specialities may be required. The People's Button (A. & N. Stores) fastens to the clothes without the need for sewing. Silver has a good form of Hus'if. Rubber-gloves. Leather-belt with pouches, swivels, &c. Bootlaces. Have a pair of long, warm boots for tent wear, and a pair of long over-all rubber boots for slipping on to go out of the tent in snowy or muddy places.

3. *Instruments.*—(See Section IV.)

4. *Stationery; Note-books; Books and Maps; Despatch box, a small copying roll, stylographic pens, and ink-bottle in wooden case.*—The descriptions of paper most useful are bank-post, tissue, and botanical. Note-

books should be made out of bank-post, be bound in parchment, and have gilt edges. It will be found a great convenience to classify observations into separate books, or distinct divisions: (*a*) an angle-book for the survey observations, barometric, &c.; (*b*) a general note-book; (*c*) notes on and numbers of natural history specimens. Such classification must be effected sooner or later if the observations are to be turned to account. Tracing-linen (sometimes called tracing-cloth) is more useful than tracing-*paper*. Strong envelopes and of large size. Labels, adhesive or tied, according to the climate, for bottles with natural history specimens, should not be forgotten. Perry's ink pellets; a little blue and red ink for the map, and some indelible brown which can be painted over, a good portable inkstand, and steel pens of various descriptions should be taken. Brandauer's "Oriental Pens" are recommended for fine work. Sketches and notes, particularly the records of angles, in pen-and-ink are to be preferred to the same in pencil, as the latter often become illegible.

The nature and the extent to which the traveller should take books and maps must be determined by his particular circumstances. A few sheets of sectional paper (*i.e.* paper with printed lines crossing at right angles) will always be found of service for making maps and plans.

5. *Appliances for Collecting.*—(See Section VIII.)

6. *Presents and Articles for Barter.*—Clasp-knives, of all sorts, are esteemed. These are most advantageously obtained direct from Sheffield and Birmingham manufacturers of repute. Spectacles are useful in many countries. Small musical-boxes, hunting-whips, field-glasses, flasks, tea, tobacco, coloured pocket-handkerchiefs, snow-spectacles, card-board plates with coloured pictures, Waterbury watches, and whistles, are all frequently appreciated. Beads are good in many parts, but judgment is required in purchasing only those sorts that are generally in fashion. Information should be sought from previous travellers. Birmingham and Venice are the principal centres of the bead manufacture. For almost all wild or partly-civilised countries special articles may be usefully carried. Inquire beforehand.

A few simple conjuring tricks, and the knowledge of how to show them off, are often of the highest use to travellers in winning the esteem and respect of their temporary hosts.

7. *Camp Equipments; Tents; Cooking Stoves; Filters; Tools; Arms.*—For Africa and hot climates generally, and where the traveller can live in

his tent, it should be square, double-roofed, and fairly roomy (see p. 25). For very rough travelling, or for journeys on which it is desirable to carry only a moderate amount of impedimenta, the pattern of Whymper's Alpine tent is recommended. Tents of this nature, 7 × 7 × 7 feet, form a moderate load for one man. Messrs. Silver have the pattern; the material should be "Willesden canvas," which has been found altogether waterproof. The tent should have a small window at the back. It is well to have an extra mackintosh floor loose. This should be one foot larger than the floor of the tent, and have tapes attached, which tie to corresponding loops on the canvas. Several extra waterproof sheets of various sizes are sure to come in handy to cover luggage, &c. One Whymper tent (Edgington's), for a mountain journey, for each man; in hot countries extra fly is needed. The tent should be made to open at both ends, and the floor should be continued up at both ends and fastened so as to stand in a vertical position to a height of at least 6 inches. Take two spare poles and spare Willesden canvas. A very light form of tent, for the use of mountaineers and others, has been invented by Mr. Mummery. It holds three men and weighs 3½ lbs. Tents of this kind may be seen at Edgington's; they are capable of improvement by the addition of a floor.

Jaeger's sleeping bags are warm enough for all ordinary cold. Eider-down bags are recommended for greater cold; each bag to be made with 2 lbs. of best eider-down; a woollen cover to be sewn over the satteen lining both inside and outside the bag; or, have two bags similarly made, with 1 lb. of eider-down each, and use them singly or in combination.

Stool and Table.—An artist in tropical countries or snow regions must by no means fail to carry some form of artist's umbrella or light sketching tent.

Rough Towels.—Buckingham's 1-snood, 4-snood, 8-snood, and cable-laid twines are recommended.

Rubber pocket-flasks holding one pint.

Kananga water (Japanese) to rub on hands and face, as a protection against mosquitoes. Tins of mustard leaves.

Filter.—A good "traveller's filter" is desirable. The "Explorer" is the most satisfactory for providing small quantities. Abyssinian pocket-filters are recommended, but are of no use for the supply of large quantities. A piece of mackintosh sewn up in a cone shape, with cane or wire round the large end to distend it, and with a piece of sponge

fitted in the neck, is better than nothing. Not only filter thoroughly, but also boil the water. Too much trouble cannot be taken to obtain pure water. More travellers have probably lost their lives through fever, and through drinking bad water than from all other causes put together. For carrying water for use on the march (or other liquids), Silver's ebonite flasks, felt-covered, with attached straps and cups, are recommended.

Cooking Stoves, &c.—Some knowledge of how to cut up an animal or prepare a fowl for the pot is very useful; and the more the traveller knows of simple cookery the better, for if he should not cook himself, he will be in a position to teach others. He should, whether he will use it himself or not, take pains to select before starting the form of portable cooking apparatus best suited to his purpose. Handles should be riveted, not soldered. Small bellows are useful. Enamelled iron cups and plates, knives, forks, and spoons must be added. (For lanterns, see p. 72.) Rob Roy cooking-stove, and Warren cooking-pot.

A supply of fish-hooks and lines of different sizes is very useful; given out to the men in camp, they will often enable them to supply themselves with food.

Take strong riding-whips, and strong twine and whipcord. The best twine commonly made is called "page-cord" (used by compositors for tying up pages of type). If rope is wanted, use Manilla.

Tools, &c.—A small leather roll, containing a chisel and a gouge or two, a small hand-vice, two files, one Δ gimlet, bradawls, small metal punches, and cold chisel, wire-nippers, pincers, screwdrivers, French nails and screws, and small fine saw, most serviceable for mending broken articles, if the travellers can use them. Leather shoemaker's awl, waxed thread. Small bellows, and a few bundles of firelighters. A light axe, and tin-opener. Buck, Holborn Viaduct, supplies excellent tools. Gum and liquid glue. Copper rivets of various sizes, and pinchers to cut the ends off. Butcher's Terror for making up loads. Lead seals and vice. Leather punch. Two-handed screw-driver, a jemmy, link-spanner, leather punching plyers. Materials and tools for mending and nailing boots, including shoemakers' thread and cobblers' wax.

Arms and Ammunition.—The nature and extent of his battery will be matters for the traveller himself to decide. For rough travel it is a question whether muzzle-loading guns may not be better than breech-

loaders. Should the latter be taken, a good double gun and a double Express rifle are useful, and also a "Transvaal," with shifting barrels for shot or bullet. Revolvers are more useful for the moral effect they produce than from any actual service they render.

8. *Medicines.*—(See Section III.)

9. *Photographic Apparatus.*—(See Section V.)

The following preliminary lists of Requisites, compiled chiefly from the catalogues of some of our principal outfitters, make no pretence to be in any way complete. Some of the articles may be superseded by improved appliances and new inventions, or may be superfluous for travellers who have not the same means or aims of those who have supplied the lists.

The traveller need not be discouraged if unable to secure completeness, for some of the greatest journeys have been made with very inadequate resources. The object here is to give him the means of selection. In the details of the process he must, as has been said before, guide himself by the special circumstances of his journey.

The traveller, whose aim is to be in light marching order, may first be given a general admonition to see that he has suitable warm and light clothing, proper medicines, a serviceable cooking-apparatus, which need weigh little more than a kettle, and concentrated forms of food to fall back on in case of need, and such saddlebags or forms of packages as may be suited for the mode of carriage he will employ.

Some Requisites for a Tropical Tour—

Double-lined tent; camp bedstead; folding tables; field hammock; mosquito curtains, or insect-puzzler, on Mr. Tuckett's plan (see *post*); head-gear and clothing (see p.); stout shooting-boots; canvas shoes; leech-gaiters,* rug, or plaid; lined umbrella, for

* Colonel Godwin-Austen says: "An effective way to prevent leeches attacking the ankles and legs, is to wear woollen stockings; then over them, round the legs, *patawas*, the woollen bandages as worn in the Kashmir Himalaya, and now served out to our troops on mountain service in India. Then, last, a pair of cotton socks tied above with tape. After adopting this plan in the Terai and Assam I never got bitten." Stout cloth gaiters with straps, *not* buttons, are preferred by many travellers to leather. They are lighter, warmer, and resist snow better.

sun;* bags, saddle, and valise; hunting-knives; patent ebonite water-bottle, covered in felt, with cups; waterproof despatch-box.

Some Requisites for a Tour in Cold Climates—

Whymper's tent; flannel shirts; under-waistcoats and drawers; long lamb's-wool stockings; woollen suit; fur coat, gloves and knitted sleeping-cap covering ears; flannel or blanket belt; woollen jersey comforters; Swiss woollen lined slippers, snow-shoes; mocassins; hair eye-screens; wool, or fur rugs; warm gloves, mittens, and portable lanterns.

Patent Norwegian cooking apparatus; sleeping-bags of woollen material or skeepskin, essential in high mountain excursions (Mr. Tuckett's pattern may be obtained at Silver's); canteens, fitted with enamelled iron ware; waterproof bags; tan canvas kit.

See also Alpine Club Report.

LIST OF MR. WHYMPER'S SOUTH AMERICAN OUTFIT.

The following list of articles taken by Mr. E. Whymper is given as representing the maximum outfit of a scientific explorer and mountaineer in a semi-civilised country. Though few will be able, or need, to imitate its completeness and scale, it may be useful for reference and selection, and is therefore given here *in extenso*—with the exception of the photographic apparatus, which have been superseded by the progress of the art.

Stationery, &c.—

Stencil-ink, brushes, and stencil-plates (various).

2 "Traveller's Inkstands" (Hachette's); inkstand in case.

Steel pens (various), including very fine sorts; stylographic pen.

Drawing pencils, brushes, pen-holders, and letter-fasteners.

Parchment and gummed labels (various), 6 gross in all.

Tissue paper (useful for various purposes, including photographic printing).

* For survey work it should have a long handle, in two pieces or joints, the lower joint being spiked to fix more firmly in the ground.

Bank-post; cream-laid papers (various sizes); blotting-paper.
Stamped and plain envelopes (various); canvas envelopes.
4 doz. memorandum books; sketch-books; gum; ox-gall; red tape.
Tracing-paper, and a roll of tracing-linen; ferro-prussiate paper.
Drawing-pins; penknives; Chinese white and water-colours; 2-foot steel rule.
Note-books, bound in parchment, with clasps; photographic register; journal and general note-books; daily notes; angle-book; boiling-point book; catalogue of collections.

Maps, Books, &c.—

Admiralty charts, maps, and works of importance, for reference on the spot.
Dictionaries and grammars for languages spoken in country to be traversed.
'Hints to Travellers'; Lockyer's 'Astronomy'; Bethune's 'Tables'; 'Admiralty Manual'; 'Sailor's Pocket-Book'; Frome's 'Surveying.'

Clothing, &c.—

9 towels; 12 flannel shirts; 2 white shirts; 16 pairs angola socks; 26 pocket-handkerchiefs; 3 neckties; 6 shirt-collars; 3 pairs mountain-boots; 1 pair ordinary boots; 1 pair lawn tennis shoes for shipboard; 4 suits, woollen, various thicknesses; dress suit; Panama straw-hat; Arctic cap; travelling-cap.
Red felt for tablecloth; large sponge and several small pieces; tooth-brushes; very thick woollen jersey; 2 rowing "sweaters"; 2 woollen comforters; 2 neck-wraps; 3 pairs knitted woollen gloves; 1 pair woollen mits; 2 pairs leather gaiters (own pattern); 2 linen masks (for snow); 2 woollen head-pieces; folding felt slippers; cork soles; small pieces of mackintosh (various); several hanks whitey-brown thread; several pieces inch-wide tape; dusters and cloths; common pins, sewing-needles, and packing-needles; down dressing-gown; very long ulster coat.

Miscellaneous.—

Two tents (own pattern) 7 × 7 × 7 feet, packed in stout canvas bags.
Sheepskin rugs laid down on felt.

Waterproof sheet 10 × 10 feet.
" " 6·6 × 6·6 feet.
4 bags of forfar (to be stuffed with hay for beds).
4 " " (" " " pillows).
Various bags (to be filled with stones or sand to keep the tents firm).
Four 100-foot lengths of Manilla rope; 6 ice-axes.
Various mackintosh and leather courier-bags and knapsacks.
Mosquito-nets; various bags of forfar; tin flasks and cans.
2 pint ebonite bottles, felt-covered, with straps (Silver's).
Cooking apparatus (from Nares' surplus stores), with attached pannikins, and small ditto.
Water-tank, with filtering sponge and tap; 2 pocket filters.
Salter's spring balance, weighing to 25 lbs.
Double gun, by Holland & Holland (rifle and shot), shot (various), gunpowder, &c.
Night-lights and candles; folding camp-chair.
Insect-net; botanical collecting-book and paper.
Knives for opening tins; brass spirit-lamp.
Geological hammer.
14 lbs. tobacco; cigars, cases, pouches, pipes; flint and steel.
14 cakes soap; camphor.
Balls of strong twine (various); screws and nails, various sizes.
3 gross glass bottles (various sizes) for insect collecting.

Medicines (various).

Presents, &c.

500 bead necklaces (amber, turquoise, &c).
250 silvered and gilt crosses, various patterns.
150 pairs of earrings and brooches.
300 eye-protectors (green, blue, white, and neutral tint glasses).
72 gilt and silvered watch-chains.
24 pairs of spectacles and eye-glasses.
18 tin dishes fitting one inside another }
25 " plates } (used also in cookery).
36 " spoons }
Silver toothpicks.

Keyless silver watch.
25 good pocket-knives, various descriptions.
6 corkscrews.
Small tape measures in brass cases.
Various plated goods.
12 circular looking-glasses.
12 mouse-traps.

Instruments.—

Silver lever watch; gold pocket-chronometer; independent seconds watch.
Repeating travelling clock, with alarum.
6-in. sextant (Cary).
3-in. transit-theodolite (Casella).
2 theodolite stands.
2 mountain mercurial barometers, Fortin (Hicks).
1 mercurial standard barometer.
11 boiling-point thermometers (various makers).
Henderson's boiling-water apparatus (Hicks).
8 aneroid barometers (Hicks, Casella, Hilger).
Telescope in sling case; field-glass in aluminium.
Thermometer in metal tube, for pocket.
Case containing maximum, minimum, and clinical thermometer.
Prismatic compass; various pocket-compasses.
Multiplying winch and measuring line.
Metallic measuring tape, 50 feet (Chesterman's).
Case of mathematical instruments.
Drawing-pens (various); Napier's compasses.
Travelling combination pocket-knife; corkscrew and whistle.
Russian furnace.
Magnesium riband.
Small musical-box.
Screwdrivers (various).

Clothing, instruments, and valuables were packed in air-tight metal uniform-cases, with outer double-varnished wooden cases. Provisions and the bulk of the goods were packed in tin, and soldered down, inside

double-varnished close-fitting wooden cases. Chemicals and articles likely to be injured by damp were in double tin cases, soldered down separately one over the other. The majority of the cases measured $28\frac{3}{4} \times 11\frac{3}{4} \times 10\frac{1}{4}$ inches. This was found a very convenient shape for mule travelling.

The whole, including provisions, amounted to 42 packages. Gross weight about 2300 lbs. Total cost of journey £1750, exclusive of cost of instruments and plant brought home in good condition.

All the articles enumerated in the above lists were taken out from England, and scarcely anything, except part of our food, was purchased in Ecuador beyond the following articles:—

Waterproof capes (ponchos); woollen ponchos; saddles; riding-whips; machetas.

These articles could have been obtained of better quality and at less cost in England.

ED. WHYMPER.

February, 1883.

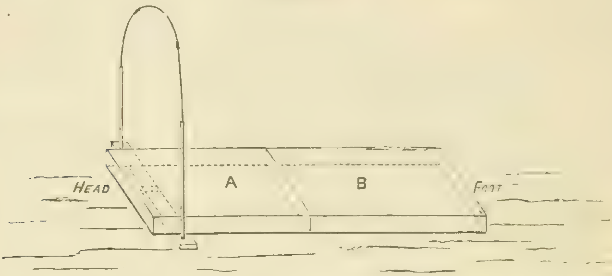
THE TUCKETT "INSECT-PUZZLER."

The form of protection, described on next page, from insects and vermin of all kinds is extremely portable, and has been found equally useful in camp and in native huts. As it is not generally known, except to Alpine travellers, it is described fully. It can be procured at Messrs. Silver's.

Take two pieces of cedar or mahogany board, $\frac{5}{16}$ of an inch in thickness, 16 inches in length, and 5 in width, and attach them endwise to one another by a hinge, or by pieces of string lacing through corresponding holes, so that they may be folded together for economy of space. At the centre of, and one inch from, the outer extremity of each board, insert very securely a female screw in brass, into which can be screwed uprights of bamboo, 18 inches in length, and about half an inch in diameter. By means of these and three light detached canes, each about 17 inches long and furnished with sockets, an arch about 34 inches in height, and of considerable strength, is formed.

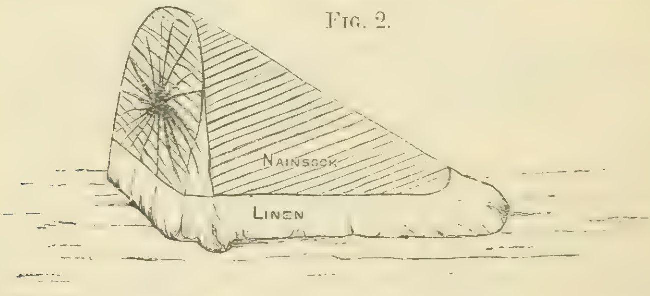
If greater head-room is desired, the length of the bamboos may be increased, and other dimensions may be modified to suit individual preferences.

Fig. 1.



Having inflated with small portable bellows an india-rubber mattress, 7 feet in length, and 26 inches in width, made in two attached sections, A and B, Fig. 1 (a cork one may be substituted, or the contrivance may be used without any mattress at all), place the united boards underneath it at 10 inches to a foot from the head-end, as in Fig. 1, and the mattress,

Fig. 2.



or the weight of the body if no mattress is available, will keep the boards and arch firmly in position.

Standing across the foot of the mattress, draw over and under it a covering, made somewhat of the shape of the foot of a sock, of which the

under portion in contact with the ground, and the sides and "toes" for a height of a foot or more above the mattress when in position, are made of strong unbleached linen, whilst the upper part is formed of "nainsook."

Pull the bag thus constructed backwards under the mattress, and over the top of the arch (securing it to the summit of the latter by pieces of tape sewn on inside), and then, creeping feet foremost from behind through the open end into the interior, draw in the pillow, reef up from inside, by means of a tape, the open end of the bag, and, winding the slack round until the material is tightly strained, secure the centre with a bow.

Thus all access of vermin or mosquitos is absolutely cut off in every direction, and the protected person, invisible himself, but able to see those outside, can sleep in peace, or read undisturbed, either by day or by the light of a candle (placed outside on a chair or stool), which passes freely through the "nainsook" envelope.

Such an arrangement in feverish districts affords at least some protection against malaria. (See p. 47.)

Mr. Mummery's Tent.

Mr. Mummery, of the Alpine Club, has devised and tested in actual use a form of tent which holds three men easily, and weighs only 3½ lbs. Tents of this kind can now be purchased at Edgington's. The area covered by the tent is 6 feet long by 4 feet wide. The end of the tent is of the form of a rectangle surmounted by an isosceles triangle.

Mr. J. Thomson's Notes.

The following outfit was provided by Mr. Thomson for his journey across Masai Land in 1883:—For carrying my clothes, books, &c., 8 boxes, of different sizes, watertight, *well rounded* at the edges, not more than 10 inches deep, and not very wide, so that they may be easily grasped when on the shoulder or head. The larger boxes are for carrying

clothes only, the smaller for a mixture of clothes with heavier articles, such as books, boots, &c. None of the boxes when filled to weigh over 50 lbs.

For clothing I have provided 1 ordinary suit of tweed clothes for the colder regions, 3 suits of tropical tweeds, and as many of white drill; 6 strong loose shirts, with pockets, and as many thin jerseys; 6 pairs of thick *woollen* stockings or socks; 1 pair of strong boots, for wet season; 2 pairs of lighter make, for the dry season, and 2 pairs of canvas shoes for camp use, and when feet are sore. Heavy boots are to be condemned for the tropics, as the feet soon become scalding hot, making travelling in the heat of the day most painful.

Canvas gaiters are of great use, to keep mud out of the boots when tramping through swamps, and to protect the legs in thorny scrub. A tropical waterproof and a comfortable ulster make up the clothing list, with the addition of such minor articles as handkerchiefs, scarves, &c.

We have next to consider camping requirements.

I have formed a very decided opinion as to the necessity of the African traveller making himself as comfortable in camp as the *circumstances* and the *extent* of the expedition will permit. The climate is so trying and varied, that to attempt "to rough it" unnecessarily is simply to invite disease, and too often death.

Impressed by experience with these convictions, I have been careful to select a fairly roomy tent, 9 feet long, of good canvas. An iron bedstead, with cork bed, and two warm Austrian blankets. A folding chair, camp-stool, and a small portable table. The latter is an immense convenience when much writing has to be done.

For short, quick trips, in which I might be away from camp for a day or two, I have provided a palkee hammock, which forms a bed and tent in one.

For carrying any sick person an ordinary string hammock is taken. A mosquito curtain makes up the list of camp furniture.

Instead of carrying an ordinary bucket canteen I have had a basket fitted up with all the necessary articles.

I, of course, take with me a small medicine-case, specially fitted with a view to the treatment of fevers, diarrhœa, dysentery, liver disease, &c., and besides, I have been careful to have some of the more useful medicines in separate bottles in case of accidents.

Among other useful articles, the following may be mentioned:—Waterproof ground sheets; roll-up case of tools; one ·577 Express rifle, one ·577 reduced to ·450, a 12 bore gun, a revolver, with ammunition to suit; two axes; a hunting knife; two bill-hooks and two reaping-hooks, to be used in camping and cutting a way through jungle and forest; diary and necessary stationery; some books, especially such as can be read and re-read.

These articles, with scientific instruments, photographic apparatus, &c., form the chief part of my equipment.

I have not thought it necessary to lay in a supply of stores, such as tea, coffee, sugar, &c., as they can be got almost as cheaply in Zanzibar. Goods for bartering must also be got there, as I should otherwise run the risk of taking out what would, to a large extent, prove to be utterly worthless.

As the country through which I have to pass is reported to be dangerous, I shall arm as many of my men as possible with short Snider rifles, and take revolvers for myself and the leaders.

December 3, 1882.

Mr. H. H. Johnston's Notes.

I have been asked to add a few hints on an African outfit. Perhaps the simplest plan will be for me to give a brief sketch of the way in which I myself travel in the interior of Africa. I have made four more or less extended journeys in Africa since 1879, visiting a great deal of the northern part of the continent, the western and the eastern, and my present form of outfit is one that experience, and perhaps individual taste, have gradually formed to a character which I find decidedly conducive to comfort and true economy. Firstly, it is to be supposed that one's baggage must be packed in a way that will render it readily adaptable to porterage, either on the heads of human porters or on the backs of beasts of burden. Consequently, the heaviest separate load should not be as a rule heavier nor larger than a man can carry, therefore you should arrange to pack all your goods in parcels not weighing more than fifty pounds. In exceptional instances, such as a tent or a bed, where the article is one and indivisible, and exceeds the weight mentioned, it

must be fastened to a pole, and arranged so that two or more men—if porters are the only means of transport—can carry it. For security against robbery, for compactness, lightness, and, above all, resistance to damp, there is nothing better than air-tight tin cases, measuring about forty inches by twenty-eight, with good locks and handles at each end. Cases of this description are cheaply made by Messrs. S. W. Silver & Co. It is well that there should be the same lock to all the boxes, so that one key—which you can attach to your watch-chain or hang around your neck, keeping a duplicate in your dispatch box—opens all.

Special instructions are given in other parts of this volume as to a scientific outfit for the prosecution of special studies in various branches of science, so that I shall say nothing about this subject, the more so as I thoroughly agree with the practical usefulness of the suggestions offered therein by competent authorities. The directions in natural history as to outfit and instruments I have particularly put to the test, and can recommend them as thoroughly practical, and emanating from the mind of an experienced traveller. As to photography and medicine, I would caution the traveller against attempting to be too elaborate, seeing that in all the fatigues and worries of transport he may find his chemicals and drugs a horrid nuisance. With regard to drugs, indeed, as you cannot hope to be an accomplished physician and the healer of all ills with which you come in contact, you would do well to confine yourself to a few simple remedies for simple forms of sickness, and these should be taken in large quantities. Quinine is the traveller's sheet-anchor. It is best procured from Messrs. Howard & Son, Stratford, E., who will, if necessary, supply it in a compressed form in small cakes. This is by far the best and most convenient mode of carrying quinine about. To roll your dose of quinine up in cigarette paper into a small pill, to moisten it with the tongue, and place it at the root of the tongue and swallow it, is the matter of a minute. Other useful and simple drugs that do not require much measuring or preparing are: Cockles' pills, as an aperient, Lamplough's pyretic saline, chlorodyne, opium, in the shape of laudanum, for sudorific purposes, castor oil, sal volatile, and Dover's powders. Vaseline and zinc ointment are excellent for the sores and ulcers of the tropics, and violet powder is a good thing to dust over the body, especially between the folds of the skin, where perspiration is likely to accumulate, in order to absorb and sweeten the excessive sweat poured out from the pores of the skin.

As regards tents, the traveller must endeavour to judiciously combine comfort with portability. He had better go to Silver's or Edgington's in the City, and choose for himself; but he should take care that he assure *himself*, first, that the material of the tent is absolutely rain-proof, and secondly, for hot climates, that it is double-lined, with a space between the two linings. This is absolutely necessary for the tropics, or the interior of the tent under the sun's rays becomes intolerable, unless there is a current of air passing between the two linings. I obtained a cheap and comfortable tent for my Kilima-Njaro expedition at Messrs. Silver's. If possible, a second, or even a third, tent should be taken for the use of one's personal servants, and for housing such of the baggage as cannot be taken into one's own tent. If an extra tent or two is placed at the disposal of the men, it has a wonderful effect in reconciling them to the severe discomforts of a journey in rainy weather.

Two most necessary items of any African outfit, however small, are a portable table and a stout portable chair, and it would be better if the traveller took two or three chairs with him (as they are very light and portable) so as to be able to offer a seat to any native of importance who may visit his tent—an attention generally much appreciated.

With regard to food: the traveller must be guided a good deal by his own tastes in eating and drinking. He has every opportunity of pleasing himself by selecting from the lists of provisions furnished by some of the great provision merchants of London, such as Messrs. Fortnum & Mason, Messrs. Crosse & Blackwell, and Messrs. J. T. Morton; but I would specially urge on him, if he is visiting the tropics, the absolute necessity for extreme moderation in the use of alcohol. Indeed, it is better to go to the extreme of abstaining altogether than to go to excess in this matter, which is remorselessly punished by nature. At the same time, alcohol is a valuable medicine and should not be excluded from the traveller's repertory. For an expedition not likely to last more than a year, the following amount will be found sufficient:—Two dozen of good champagne, three bottles of sherry, four bottles of brandy, and four of whiskey. Claret, burgundy, and port travel badly, although as tonics and blood-making wines they are among the best. If the traveller is in any part of Portuguese Africa he will probably be able to obtain the excellent Vinho Tinto of Lisbon, which can be recommended as a very wholesome wine. Except under extraordinary circumstances, such as

accidents, or deadly faintness, alcohol should never be taken in the day-time, but reserved for the evening, and if the want of it is then felt, it should preferably be taken in the form of champagne, or brandy or whisky and water. The practice of so many German travellers of taking small quantities of neat brandy or other spirit in Africa is most deleterious, and if pursued for any length of time will inevitably prove fatal.

If the traveller is a draughtsman, he should of course provide himself with paper and artist's materials; but these should be as simple as possible, for the true artist can make an accurate and effective drawing with very simple materials. These materials should consist of several good stout note-books with paper of fair quality, ruled with faint blue lines. Such will be very useful for hasty sketches made in conjunction with written notes, and the traveller will find the blue lines assist him greatly in the accuracy of his drawing. Two or three blocks of white Whatman's paper, mounted with covers, and a pocket to contain loose sheets, will be found sufficient for more elaborate drawings, either in black and white, or in colour. These, for convenience, should be about twelve inches by nine in size, and the paper should be nearly smooth. A good box of water-colours in tubes should be taken. The colours are carried much better in tubes than in porcelain pans, for the latter are liable to the attacks of insects, and are soon ruined by damp. The best colours for ordinary purposes are the following:—Chinese White, Lemon Yellow, Mutrie Yellow, Orange Cadmium, Yellow Ochre, Raw Sienna, Burnt Umber, Vandyke Brown, Ivory Black, Antwerp Blue, French Blue, Cobalt, Crimson Lake, Scarlet Vermilion, Indian Red, Venetian Red, and Emerald Green. An extra quantity of Chinese White and liquid Indian Ink in small bottles, and Indian Ink in stick, should be taken for making black-and-white studies. The traveller will be sure to make most of his minor and more rapid sketches in ink, and should be sure that he has good writing-ink for the purpose. Stephenson's black ink is the best. For pencil notes the best pencils are F and H B, and French Conté chalk in cedar, No. 1, will be found very useful, especially when the work done in the chalk is gone over with a pen and finished in ordinary black ink. This gives a very rich and solid effect to the drawing, and, moreover, prevents the chalk from rubbing to a very great extent. I have myself, in earlier days, lugged quantities of oil paints and canvas about Africa with an amount of discomfort and worry quite dispropor-

tionate to the small results of an occasional study in oils, which, if you are any artist at all, can be done almost as effectively in water colours. Indeed, except for the special purpose of indicating the colour of a man's skin, or of that of a bird, or mammal, or lizard, or the tint of a flower's corolla, I should recommend all travellers to confine themselves to black and white in their reproductions of the objects of interest or the scenery that they meet with, and not to inflict on us the feeble, washy water-colour pictures which they intend to represent the grandeurs of tropical scenery.

As regards food for the mind I cannot too strongly recommend all travellers to supply themselves with quantities of light literature. By "light," I do not mean frivolous in character, but devoid of great material weight, so that it can be easily packed and readily transported. There are a great many standard works now published in cheap editions in paper covers, and these, together with a supply of good novels, sensational tales, old magazines, and reviews, should be taken. Although the traveller should endeavour to supply himself with books that are worth reading and re-reading, still, it is astonishing with what pleasure he will peruse the veriest rubbish in the wilderness, and really crave for anything that may serve to distract his mind at times from the savagery around him.

Finally, I would recommend such travellers as have not the time to work out a systematic equipment for themselves, and who desire to spare themselves trouble as well as time in the matter, to consult with Messrs. Silver, of Cornhill, on the subject. This firm has supplied travellers, including myself, with their outfit, and knows—or ought to know by this time—exactly what is needed for every part of the globe. As they retain lists of all the articles supplied for various expeditions, any one, by referring to these lists—as for instance the outfit of my Kilima-Njaro expedition—will be sufficiently guided in their choice.

For further information on *Outfit*, especially in arid countries, the intending traveller is referred to pp. 9-11 of Mr. Galton's 'Art of Travel' (5th Edition).

CANOEING.—*By* J. COLES.

Choice of a Canoe.—In making choice of a canoe the traveller must bear in mind that, in all probability, there will be rapids in the river, which will necessitate a portage being made, and that the canoe may have to be carried over rough ground for a considerable distance. For this reason, it is far better to take two canoes of moderate size than one large one, beside which, a small canoe is much more easily handled in bad water, and even should it become necessary to carry a large load, this can easily be done by lashing two small canoes together, at about one yard apart, and laying a platform across them, on which to place the stores, &c. This, however, should not be done in dangerous and rapid rivers. The following remarks do not, therefore, apply to large canoes, which, having nearly the stability of a boat, may be handled in the same manner.

Paddles.—It will generally be found that the native paddles will be best suited for the work. The double-bladed paddle, such as is used with canoes in this country, is quite useless on a rapid and dangerous river.

Sail.—The sail should be made of duck, or some such light material, fastened to a light yard at each end, and its hoist should be about twice its breadth; its size must be in proportion to the canoe, the hoist being about one-fourth of the canoe's length. The mast should be as light as possible, with a hole at the top for the halliards to pass through freely. The end should be stepped in a chock in the bottom of the canoe (when in use), and it should be lashed to one of the stays, or cross-pieces of the canoe. The sail should never be used unless the wind is steady and abaft the beam, and the halliards should be taken to the after part of the canoe in order to stay the mast, and secured in such a manner that it can be instantly let go, when the sail will at once fall, and undue pressure on the canoe relieved.

The Tow-line.—Too much attention cannot be paid to this important article. It should be light, but of the best material (such as the rope used by the Alpine Club), as its giving way at a critical moment in a rapid is sure to be attended with most serious results.

Loading the Canoe.—The packages should not exceed 50 lbs. in weight, as they may have to be carried long distances over portages, and care must be taken not to overload the canoe. Natives, who are all good

swimmers, and have nothing to lose by a capsize, are very apt to put more into a canoe than is safe, so that it is a matter in which the traveller should use his own discretion.

In ascending a rapid river, keep close to one of its banks, and endeavour to take advantage of eddies. It will often happen that, owing to the strength of the stream, no headway can be made with the paddles, in which case recourse must be had to poling or tracking. In the event of the former, the poles should be straight and tough, and as long as can be conveniently carried in the canoe. Natives generally stand up to pole, but this the traveller should not attempt to do, or he will in all probability either fall overboard, or capsize the canoe, or both. In tracking, as great a length of line as possible should be used, as a sheer of the canoe in a rapid, with a short line, will often end in a capsize. Only two men should remain in the canoe, one in the bow with a pole, and the other in the stern with a paddle to steer; this man should also have his pole handy. The line should be made fast to one of the stays in the bow of the canoe, and *never to a towing mast*, as in a boat; as in passing round bad corners, or places where there are snags, and where it is necessary to give the canoe a wide sheer, the leverage of the mast, if the line were fastened to the top of it, would pull the canoe over. The man in the bow, however, should always have his knife handy to cut the tow-line, should necessity arise for his doing so. In tracking, when a river passes through sandy soil, the men on the line should keep at some little distance from the edge of the banks, as it is likely to give way under their weight, and precipitate them into the river. Several men lost their lives in Fraser River, in the early days of the gold discovery, by neglecting this precaution.

In crossing from one bank of a river to the other above a rapid, be careful to ascend the river for a considerable distance before attempting to do so; and then make the crew paddle as hard as they can, keeping the head of the canoe, if anything, rather down the stream, as in the case of a rapid river you would only lose ground by trying to fight against it.

In descending a river, the traveller should keep a look-out ahead for snags and places where the river is narrowed in between hills, as in such places there is nearly sure to be a rapid which may be so bad as to render navigation impossible. In all cases before descending an unknown

rapid, he should land and inspect it throughout *its entire length* before attempting to run it in the canoe. When descending a rapid, care must be taken to keep steerage way on the canoe, as this will be needed to avoid rocks, or whirlpools. These latter are very serious dangers, as they generally do not remain fixed in one spot, but move about within a certain distance of a centre. There are, however, in most cases, short intervals when they break up, and that is the time to make a dash past them. To attempt this when they are in full swing could only end in the loss of the canoe and its occupants.

Boating.—*By* J. Coles.

When a traveller has to proceed for some distance overland before reaching the river or lake he purposes to navigate, he must of necessity provide himself with a boat constructed in such a manner as to be easily transported, either by being built in sections, that can be put together and taken to pieces at pleasure, or by taking one of the collapsible boats, such as Berthon's. If the former, he cannot do better than to have one built of Spanish cedar, on the same plan as that which was constructed for Mr. H. M. Stanley, by Mr. James Messenger, of Teddington, with such modifications as may be necessary, when the means of transport, and the nature of his journey, have been duly considered. Collapsible boats, though very useful for ferrying across lakes or rivers, cannot, where a boat of other construction is available, be recommended for a continued exploration; they are, however, constructed of different sizes, and full particulars concerning them can be obtained from the Berthon Boat Co., 50, Holborn Viaduct, E.C.

If the exploration is to be commenced at the mouth of a river, a whale-boat will be found to be the best form of boat, for the following reasons. Being steered by an oar, it is more easily handled in surf or a rapid; it is generally faster than boats of the same size of ordinary build; it will carry a good cargo, sail well off the wind, and is the best boat built for crossing the bars of rivers, or landing through a surf. Such a boat can generally be purchased at foreign ports, with their oars and sail, and should be well overhauled before starting.

Boat-sailing cannot be taught by any book, and certainly not by a

few short notes of this description. The traveller, therefore, who intends using a boat for exploration, should gather some experience before starting, which can be done at any fishing village on the coast. This will be the more necessary if he intends to use his boat on a lake, or for sailing along the coast, from the mouth of one river to another, and the following hints may, it is hoped, be useful to those who have had but small experience in boat-sailing.

When under sail, never, *under any circumstances*, allow the sheet to be made fast; a turn should be taken round a cleat, and it should be held by one of the crew ready to let go at any moment. Do not let the crew stand up, or sit on the gunwale. When about to round-to, remember that you cannot carry the same canvas on a wind that you can before it. If caught in a squall, put down the helm at once, ease the sheet, and if the squall is a bad one, lower the sail while it is still shaking. When approaching a danger, such as a rock, do not stand on if you are in doubt about weathering it, but go about in time, and have an oar ready to help the boat round if she appears likely to miss stays. Never carry too much sail, as there is considerable danger in doing so, and a boat will often sail faster with a reef taken in, than she will when unduly pressed. If necessary to take in a reef when sailing *on a wind*, do not luff, but check the sheet, lower the sail sufficiently to shift the tack, gather the sheet aft so that the men may take in the reef without leaning over the gunwale, shift the sheet, hoist the sail, while the sheet slack, and do not haul the sheet aft until the men are again in their places.

Rowing.—This can only be acquired by practice, and though the traveller will seldom be called on to take an oar himself, circumstances may arise when he may have to do so, and we would, therefore, advise him to learn how to handle an oar before leaving England. Under ordinary circumstances, rowing on a river is sufficiently simple, and calls for no special instructions. The case, however, is very different when a river bar has to be crossed, or a landing made on a beach where a surf is breaking, and in either case it will be well to remember the following hints. On approaching the shore, a surf when seen from seaward never looks so bad as it really is. Where possible, a landing should not be attempted until opposite a village where the natives will be ready to assist the moment the boat touches the beach. When the surf is heavy, the boat should be backed in, pulling a few strokes to meet each heavy

sea, and then backing in again until the shore is reached. The great thing to avoid is, letting the boat get broadside to the sea, as she will then capsize; a steer-oar should always be used, as a rudder is of little use in a surf, when backing in.

In crossing a bar, if there is a good, strong, fair wind, it will generally be best to cross under sail; but if the wind is light or variable, this should never be attempted. When rowing, the crew should be cautioned to keep their oars out of the water when the sea breaks round the boat, and to commence rowing again as quickly as possible afterwards. As even in the most experienced hands a boat will often be swamped on a bad bar, it will be well, before attempting to cross it, to prepare for a swim by removing all superfluous clothing, and see that everything that will float in the boat, should be left free to float, while things that will sink, such as fire-arms, &c., should be securely fastened to the thwarts.

The remarks given on canoeing with regard to loading, to ascending and descending rapid rivers, are equally applicable to boating under similar circumstances, with the following exceptions. In towing, a short mast should be used to which the line is made fast; this is stepped in the same place as the mast, and should be stayed, so as to resist the strain of the tow-line. Paddles will often be found useful in weedy rivers where the oars get entangled. As a whale-boat empty will weigh about five hundredweight, more care must be taken at portages than in the case of a canoe, which can be lifted bodily over obstacles. The stems of small trees, or the oars should be laid down under the boat, and, where possible, sharp rocks must be avoided or moved out of the way. In a rapid, two men should be in the bow with poles ready to fend off from rocks, and the most experienced man of the crew should be in the stern with the steer-oar.

Although in the foregoing remarks special reference has been made to whale-boats, the hints given are equally applicable to boats of other construction, which should, however, for river work, crossing a bar, or landing through a surf, be fitted with a steer-oar in addition to the rudder. Awnings should be taken, but in rapid rivers, and when under sail, they cannot be used.

Mountain Travel.—*By* Douglas W. Freshfield. *President of the Alpine Club.*

The Highlands of Central Asia, and the ranges of western North America, are among the fields likely next to attract explorers. If their exploration is to be thorough, travellers must take with them some knowledge of glacial phenomena. They must learn to know glaciers and moraines when they see them, to distinguish between ice and *névé*, permanent and temporary snowbeds. They must also be able to climb summits sufficiently high to command the recesses of the chain and the secrets of the snow world. In order to do this, they must be at the pains to acquire at least the rudiments of the mountain craft which has been brought to perfection by three generations of Alpine peasants. Without these qualifications, even surveyors will find themselves obliged to leave large and, to the physical geographer and geologist, singularly interesting tracts of country ill-mapped and imperfectly explored, and they will run the risk of bringing away very erroneous and incomplete impressions of the phenomena of great mountain chains. The practised mountaineer is free both from the fears and the rashness of the less experienced traveller, or the native of the Himalayas, the Andes, or the Caucasus. He is not likely to be deterred from visiting a remote valley because ice and snow, and possibly steep and rocky ridges (held impassable by the native hunters), intervene between him and it; on the other hand, he will not start on such an enterprise without every appliance that may enable him to conquer the difficulties of the way; he will not walk across a *névé* without a rope; he will not be frightened into retreat by the first crevasse, or stopped by a hard-frozen slope.

Ropes and ice-axes, procurable at Hill's, 4, Haymarket, are essential. It is still more essential that their proper use (up to the present time hardly known outside Europe) should be learnt. This may best be done in an Alpine tour, with an experienced glacier guide. Travellers without such experience had best keep to frequented passes, or below the snow-level. They will be most in danger when they perceive it least, and will imperil the lives of themselves and their companions. Icecraft, like seamanship, has to be learnt. A party of three is the smallest consistent with safety above the snow-line; and, whatever the number, the majority

in any expedition of difficulty, should be experienced climbers. Such expeditions will best be made from a base where the heavier luggage and attendants are left.

The best scheme for mountain exploration is one which neither limits the traveller to a single valley or district, nor carries him straight on from point to point, but allows for various short expeditions from a succession of centres, at which he can leave his camp and heavy luggage.

The effect of rarefied air at great heights in reducing the powers of the human frame is a subject on which precise knowledge is still wanting. Probably no one has yet closely approached the limit at which the exertion of walking uphill becomes impossible to a person in normal health and accustomed to great elevations. It lies, therefore, considerably above 23,000 feet. On the other hand, mountaineers agree that their powers diminish perceptibly as they ascend above 12,000 feet. In De Saussure's generation both he and his guides were, at 15,000 feet, on Mont Blanc, unable to do more than advance a few yards at a time, while men of science now spend three days and nights on the summit of Mont Blanc, and modern climbers feel little or no inconvenience 2000 feet higher on the difficult peaks of the Caucasus, and can still climb and observe between 22,000 and 23,000 feet in the Karakoram. Probably up to 18,000 feet the body acclimatizes itself to the upper air; and "training" is therefore one of the best preventives of mountain-sickness. Chlorate of potash lozenges are said to have been used with advantage as a palliative. The inconveniences felt on high ascents arise in some part from indigestion, and light but frequent meals (*e.g.* soup at starting, peptonised meat sandwiches and chocolate and cold tea during the climb) will be found very efficacious in avoiding bodily discomfort. A scientific investigation of the process by which the human frame adapts itself to high altitudes has recently been made by M. Vallot. (See Levasseur's 'Les Alpes,' Paris, 1889; Geographical Journal, January, 1893; and Mr. Conway's forthcoming work on the Karakoram.) The subject is complex, involving both local and personal conditions, and demands further experiment and research; all dogmatic statements must at present be received with reserve.

Next to the rarity of the air frostbite is the most formidable enemy of the climber who attempts great altitudes. Satisfactory foot-gear has

not yet been devised. Some modification of Arctic expedients suitable for rock-climbing is wanted. The feet must not be compressed and the circulation impeded. Generally foreign mountaineers pay more attention than Englishmen to climbing-shoes and crampons. The ordinary hob-nail is good enough for most places where an explorer ought to go, but crampons may undoubtedly often enable their wearers to reach a point which would be unattainable to them by stepcutting. They can be obtained of the Albion Iron and Wirework Co., Red Lion Street, E.C. The straps should be of hempwebbing, not leather, ¾ inch wide, to be obtained at Buckingham's.

The special requisites for snow and ice expeditions are included in Mr. Whymper's List. His tent, alpine sleeping bags, snow spectacles, felt-covered water-bottles, self-cooking souptins, chocolate, warm covering for hands and feet, strongly nailed and easy boots, cloth gaiters, soap-cerate plaister, Lloyd's cold cream for sunblistering, are among the chief requisites for high exploration. Take plenty of spare dark glasses for use by porters in crossing snow passes. Field-glasses are much appreciated as presents by most mountain people, and spare ones should be taken.

Directions as to the observations, which may easily and profitably be made with regard to the present and past nature and extent of glacial action, the rate of movement of glaciers and the advance or retreat of their extremities, the snow-level, the extent and limit of forests and plants in mountain districts, and the relations of ranges to winds, rainfall, and climate, will be found in subsequent sections. (See p. 394.)

General information on many subjects, both scientific and practical, connected with mountaineering, is given in a compact form by the late Mr. John Ball in his Introduction to 'The Alpine Guide,' published separately by Messrs. Longmans (2s. 6d.), or, of more recent date, in the "Introductory Sections" to Murray's 'Switzerland' (Edition 1892), and the *Badminton* Volume on Mountaineering (1892), edited by Mr. Clinton Dent. The last-mentioned book should be studied carefully by any traveller proposing to himself serious mountain exploration. He will find a special chapter from my pen devoted to 'Mountaineering beyond the Alps.'

ORTHOGRAPHY OF GEOGRAPHICAL NAMES.

In 1885 the Council of the R.G.S., impressed with the necessity of endeavouring to reduce the confusion existing in British maps with regard to the spelling of geographical names, in consequence of the variety of systems of orthography used by travellers and others to represent the sound of native place-names in different parts of the world, formally adopted the general principle which had been long used by many, and the recognition of which had been steadily gaining ground, viz. that in writing geographical native names vowels should have their Italian significance and consonants that which they have in the English language.

This broad principle required elucidation in its details, and a system based upon it was consequently drawn up with the intention of representing the principal syllabic sounds.

It will be evident to all who consider the subject, that to ensure a fairly correct pronunciation of geographical names by an English-speaking person an arbitrary system of orthography is a necessity. It is hardly too much to say that in the English language every possible combination of letters has more than one possible pronunciation. A strange word, or name, even in our own language is frequently mispronounced. How much more with words of languages utterly unknown to the reader.

The same necessity does not arise in most continental languages. In them a definite combination of letters indicates a definite sound, and each nation consequently has spelt foreign words in accordance with the orthographic rules of its own language.

It was therefore not anticipated that foreign nations would effect any change in the form of orthography used in their maps, and the needs of the English-speaking communities were alone considered.

The object aimed at was to provide a system which should be simple enough for any educated person to master with the minimum of trouble, and which at the same time would afford an approximation to the sound of a place-name such as a native might recognise. No attempt was made to represent the numberless delicate inflexions of sound and tone which belong to every language, often to different dialects of the same language. For it was felt not only that such a task would be impossible, but that an attempt to provide for such niceties would defeat the object.

The adoption by others of the system thus settled has been more general than the Council ventured to hope.

The charts and maps issued by the Admiralty and War Office, have been, since 1885, compiled and extensively revised in accordance with it. The Foreign and Colonial Offices have accepted it, and the latter has communicated with the Colonies requesting them to carry it out in respect to names of native origin.

Even more important, however, than these adhesions is the recent action of the Government of the United States of America, which, after an exhaustive enquiry, has adopted a system in close conformity with that of the R.G.S., and has directed that the spelling of all names in their vast territories should, in cases where the orthography is at present doubtful, be settled authoritatively by a Committee appointed for the purpose.

The two great English-speaking nations are thus working in harmony.

Contrary to expectation, but highly satisfactory, is the news that France and Germany have both formulated systems of orthography for foreign words, which in many details agree with the English system.

The Council of the R.G.S., by printing the Rules in 'Hints to Travellers,' and by other means, have endeavoured to ensure that all travellers connected with the Society should be made aware of them.

To this end, and with a view to still closer uniformity in geographical nomenclature in revisions of editions of published maps, a gigantic task, requiring many years to carry out, the Council have decided to take steps to commence tentatively indexes of a few regions, in which the place-names will be recorded in the accepted form.

RULES.

The Rules referred to are as follows:—

1. No change is made in the orthography of foreign names in countries which use Roman letters: thus, Spanish, Portuguese, Dutch, &c., names will be spelt as by the respective nations.

2. Neither is change made in the spelling of such names in languages which are not written in Roman character as have become by long usage familiar to English readers: thus Calcutta, Cutch, Celebes, Mecca, &c., will be retained in their present form.

3. The true sound of the word as locally pronounced will be taken as the basis of the spelling.

4. An approximation, however, to the sound is alone aimed at. A system which would attempt to represent the more delicate inflexions of sound and accent would be so complicated as only to defeat itself. Those who desire a more accurate pronunciation of the written name must learn it on the spot by a study of local accent and peculiarities.

5. *The broad features of the system* are:—

(*a*) That vowels are pronounced as in Italian and consonants as in English.

(*b*) Every letter is pronounced, and no redundant letters are introduced. When two vowels come together, each one is sounded though the result, when spoken quickly, is sometimes scarcely to be distinguished from a single sound, as in *ai*, *au*, *ei*.

(*c*) One accent only is used, the acute, to denote the syllable on which stress is laid. This is very important, as the sounds of many names are entirely altered by the misplacement of this "stress."

6. Indian names are accepted as spelt in 'Hunter's Gazetteer of India,' 1881.

7. In the case of native names in countries under the dominion of other European Powers in whose maps, charts, &c., the spelling is given according to the system adopted by that Power, such orthography should be as a rule disregarded, and the names spelt according to the British system, in order that the proper pronunciation may be approximately known. Exceptions should be in cases where the spelling has become by custom fixed, and occasionally it may be desirable to give both forms.

8. Generic geographical terms, *e.g.* those for Island, River, Mountain, &c., should be as a rule given in the native form. In the case of European countries, translation into English, where this has been the custom, should be retained, *e.g.*, Cape Ortegal, not Cabo Ortegal, River Seine, not Fleuve Seine.

N.B.—On any printed map or MS. document, an explanatory table giving the English equivalents of the generic terms used, should of necessity be inserted.

The following amplification of these rules explains their application:—

Letters.	Pronunciation and Remarks.	Examples.
a	*ah*, *a* as in *father*	Java, Banána, Somáli, Bari.
e	*eh*, *a* as in *fate*	Tel-el-Kebír, Oléleh, Yezo, Medina, Levúka, Peru.
i	English *e*; *i* as in *ravine*; the sound of *ee* in *beet*. Thus, not *Feejee*, but	Fiji, Hindi.
o	*o* as in *mote*	Tokyo.
u	long *u* as in *flute*; the sound of *oo* in *boot*. *oo* or *ou* should never be employed for this sound .. Thus, not *Zooloo*, but	Zulu, Sumatra.
	All vowels are shortened in sound by doubling the following consonant.	Yarra, Tanna, Mecca, Jidda, Bonny.*
	Doubling of a vowel is only necessary where there is a distinct repetition of the single sound.	Nuulúa, Oosima.
ai	as in *aisle*, or English *i* as in *ice*	Shanghai.
au	*ow* as in *how* Thus, not *Foochow*, but	Fuchau.
ao	is slightly different from above	Macao.
aw	when followed by a consonant or at the end of a word, as in *law*	Cawnpore.
ei	is the sound of the two Italian vowels, but is frequently slurred over, when it is scarcely to be distinguished from *ei* in the English *eight* or *ey* in the English *they*.	Beirút, Beilúl.
b	English *b*.	
c	is always soft, but is so nearly the sound of *s* that it should be seldom used. If *Celébes* were not already recognised it would be written *Selébes*.	Celébes.
ch	is always soft as in *church*	Chingchin.
d	English *d*.	
f	English *f*. *ph* should not be used for the sound of *f*. Thus, not *Haiphong*, but	Haifong, Nafa.
g	is always hard. (Soft *g* is given by *j*) ..	Galápagos.
h	is always pronounced when inserted.	
hw	as in *what*; better rendered by *hw* than by *wh*, or *h* followed by a vowel, thus *Hwang ho*, not *Whang ho*, or *Hoang ho*.	Hwang ho, Ngan hwi.

* The *y* is retained as a terminal in this word under Rule 2 above. The word is given as a familiar example of the alteration in sound caused by the second consonant.

Letters.	Pronunciation and Remarks.	Examples.
j	English *j*. *Dj* should never be put for this sound.	Japan. Jinchuen.
k	English *k*. It should always be put for the hard *c*. Thus, not *Corea*, but	Korea.
kh	The Oriental guttural	Khan.
gh	is another guttural, as in the Turkish ..	Dagh, Ghazi.
l m n	As in English.	
ng	has two separate sounds, the one hard as in the English word *finger*, the other as in *singer*. As these two sounds are rarely employed in the same locality, no attempt is made to distinguish between them.	
p	As in English.	
ph	As in *loophole*.	Chemulpho, Mokpho.
th	stands both for its sound in *thing*, and as in *this*. The former is most common.	Bethlehem.
q	should never be employed; *qu* (in *quiver*) is given as *kw*. When *qu* has the sound of *k* as in *quoit*, it should be given by *k*.	Kwangtung.
r s sh t v w x	As in English.	Sawákin.
y	is always a consonant, as in *yard*, and therefore should never be used as a terminal, *i* or *e* being substituted as the sound may require. Thus, not *Mikindány*, *wady*, but not *Kwaly*, but	Kikúyu. Mikindáni, wadi. Kwale.
z	English *z*.	Zulu.
zh	The French *j*, or as *s* in *treasure*. ..	Muzhdaha.
	Accents should not generally be used, but where there is a very decided emphatic syllable or stress, which affects the sound of the word, it should be marked by an *acute* accent.	Tongatábu, Galápagos. Paláwan, Saráwak.

TABLE OF SOUND EQUIVALENTS ADOPTED FOR THE TRANSLITERATION OF GEOGRAPHICAL NAMES BY GREAT BRITAIN, UNITED STATES, FRANCE, GERMANY, AND SPAIN.

Great Britain.		United States.	France.	Germany.	Spain.	
a	as in *father*	a	a	a ä	a	
e	as in *benefit*	e	e	e	e	
i	as in *ravine*	i	i	i	i	
o	as in *mote*	o	o	o	o	
u	as in *flute*	u	u	u	u	
ai	as *i* in *ice*	ai	ai	ai		
au	as *ow* in *how*	au	au	au		
ao	as in *Macao*	ao		ao		
ei	as in *eight*	ei				
		ö	œ	ö	œ	As in French *eux*.
		ü	ü	ü	ü	
b	as in English	b	b	b	b	
c	soft	c	c	c	c	
ch	as in *church*	ch	ch or tch	tsh	ch	
d	English *d*	d	d	d	d	
f	,, *f*	f	f	f	f	
g	hard *g*	g	g	g	g	
h	always aspirated	h	h	h	h	
j	English *j*	j	j or dj	dj	y	
k	,, *k*	k	k	k	k qu	
kh	Oriental guttural	kh	kh	kh	j	
gh	,, ,, ...	gh	gh	gh	j	
l	English *l*	l	l	l	l	
m	,, *m*	m	m	m	m	
n	,, *n*	n	n	n	n	
ng	as in *finger* and *singer* ..	ng				
p	English *p*	p	p	p	p	
ph	as in *loophole*	ph				
kw	English *qu* in *quiver* ..	kw		kw	qu	
r	English *r*	r	r	r	r	
s	,, *s*	s	s	s	s	
t	,, *t*	t	t	t	t	
v	,, *v*	v	v	v	v	
w	,, *w*	w	w	w	w	
x	,, *x*	x	x	ks	x	
y	as in *yard*	y	y	y	y	
z	English *z*	z	z	z	z	

III.

MEDICAL AND SURGICAL HINTS.

By Surgn.-Major Thos. Heazle Parke, Hon. D.C.L., Hon. F.R.C.S.I., &c.*

1. Personal Care of Health.

It is very desirable that persons who are thinking of travelling or residing in tropical climates should be sure that their physique warrants the venture before making a change from the temperate residences of the northern or southern hemispheres. Persons of good constitution and regular and temperate habits can, undoubtedly, with judicious care maintain a fair state of health in the tropics. And even those who have been by no means very strong at home can with some extra care do very well in most parts of even the hottest climates, if peculiar circumstances make the change otherwise very desirable. All immigrants to hot climates should be instructed in certain invariable rules, deviation from which is always accompanied by more or less risk.

The surface of the body should, as far as possible, be kept at an equable temperature. On account of their non-conducting properties, the under garments should be of wool, or a mixture of silk and wool, which is lighter. As is well known, wool owes its non-conducting property to the tortuosity of its fibres. All woollen garments, on this account, and especially the looser ones, contain a large quantity of imprisoned air, which is the real non-conductor. For the same reason, two or more fine woollen shirts will be found much more efficient than a single coarse one, on account of the layer of air retained between. The fine flannel shirts are, accordingly, to be preferred, because the number worn can be so easily adjusted to varying temperatures; and it is obviously much better on that account to be provided with a large number of them, than a small number of

* This section was prepared shortly before the writer's premature death.

thick and heavy ones. Sleeves can be dispensed with in the great majority of the number; when several shirts are worn, one only should be provided with sleeves. In regions where the temperature of the night differs but little from that of the day, a fine flannel shirt should be worn next the skin, while the rest of the body and limbs may be protected with any thin cotton or linen fabric. On the other hand, in the neighbourhood of mountain ranges, or on high table lands, when the diurnal range of temperature is very considerable, care must be taken, either to wear a complete woollen suit at all times, or to change before sunset. Sudden chill is, in the experience of the present writer, the most fertile source of tropical fever.

Night clothes (pyjamas) should consist of an India flannel shirt opening down the front, and secured with linen buttons or with tapes; and a long, wide pair of trousers of the same material, provided with feet to keep out insects, which can be conveniently drawn together by a running string. In very warm regions, the latter garment may be of silk.

All flannel textures should be of wool throughout, and made to fit *very loosely*, as they necessarily shrink in washing.

Other garments which will be found useful are: lined and perforated chamois-leather under-vests, which are excellent protection against cold, penetrating breezes; long woollen comforters, and a long, wide silk scarf for winding around the waist. The latter is often used in very hot climates, with a roomy woollen shirt next the skin—fitting loosely around the neck, and reaching only to the hips—and a thin linen or calico trousers. The scarf (Kāmārbānd) is then swathed around the abdomen and loins in two or three folds. In the majority of instances, a fine flannel shirt, short, thin, loose calico drawers, a loose fitting Norfolk jacket buttoned to the throat, and a pair of thin serge trousers or knickerbockers, will be found to form a very eligible tropical suit; gaiters or putties protect the shin if necessary.

The head and spine should be protected with great care.

A well-fitting ventilated pith helmet forms an excellent protection against the vertical rays of the mid-day sun; the more oblique rays of morning and evening are shaded off by the use of a curtain descending from the rim of the helmet. It can be folded up around the helmet, or

removed during the middle period of the day, if more convenient. A woollen spinal pad is absolutely necessary to protect the spinal cord from the tropical sun. A white or green covered umbrella is also indispensable to the tropical traveller.

The army regulation helmet is the best known design.

Avoid chills, draughts, and wettings.

When on board ship, sleeping opposite open ports or under a wind sail, is often followed by fever. At the time of landing, too, there is great danger from the effects of the sudden change from the warm sea breeze to the cold land breeze in the evening. I am convinced that a great deal of the fever which gives many tropical coasts so bad a name among European travellers might be avoided by having regard to this precaution. On approaching land, the traveller is very usually tempted, on coming up from the almost Turkish-bath temperature of the saloon, where he has been lolling about in the minimum quantity of dress, to stand for some time on deck to *enjoy* this refreshing breeze. A large proportion of the worst cases of tropical fever, dysentery, rheumatism, and pleuro-pneumonic affections are ushered in in this way. Sleeping on deck should be avoided. Evening chills are also a prominent factor in the causation of disease in tropical highlands, where the fall of temperature is usually very considerable. Also, in marching through hilly districts of sub-tropical regions, where the ascent of an eminence is necessarily attended by profuse perspiration, and the summit furnishes the chilly breeze which rapidly checks it; the consequent chill, which the work of descent is not sufficient to check, is very generally followed by fever.

In crossing Equatorial Africa, the members of the Emin Pasha Relief Expedition found that *every wetting meant an attack of fever.* The frequent wading of streams was one of the prominent and oft-repeated difficulties to be encountered; every such operation was followed by an attack of fever—*to man and beast alike!* A drenching tropical shower had the same effect. It need hardly be added that sitting in damp clothes should be avoided.

On completing a day's journey—with or without a wetting—the underclothing, at least, should be changed without a moment's delay.

Use of mosquito curtains.

The use of protective coverings against the attacks of this tropical pest is a consideration which cannot be too strongly impressed upon the intending traveller. A well-prepared mosquito curtain will, of course, also protect the person from the attacks of other troublesome insects. The "Tuckett Insect-Puzzler," which has been described and figured on page 22 (see Hints), will be found a thoroughly efficacious form of protection against the troublesome invasions of insects in general. The traveller should also provide himself with mosquito netting, with which he can envelop himself, if obliged to dispense with the carriage of any elaborate apparatus. A protective covering can then be always improvised by taking a piece of netting, about seven yards long by four wide, the extremities of which should then be carefully united so as to form a cylinder. One of these may be bound with calico, and furnished with a running string; the other should be fastened up and confined by a tightly strained copper wire fastened in a groove let into the outer margin of a circular piece of flat deal board, about one foot in diameter; to the centre of this board the end of a strong coil of cord is fixed. Such curtains can always be fixed in position at a moment's notice, whenever the traveller's bed or hammock has to be arranged for the night. The long cord may be thrown over the cross-tie of a rafter of a hut, over a branch of a tree, or be hitched to the pole of a tent, carrying with it to any desired height the circular piece of board which supports the curtain, and the latter may then be spread over the bed and tucked beneath it, or secured with a running string if necessary.

It has been said that the mosquito curtain will also be found protective against the malarial poison, but of this I am not at all convinced. Apart from saving the traveller from immediate annoyance, the careful use of the mosquito curtain is also preventive of the remoter evil of the introduction of the *bilharzia hæmatobia* into the circulation, with the resulting evils of hæmaturia and anæmia.

Smoke of any kind keeps away insects, particularly when due to burning cow-dung.

In malarious districts, the poison is more concentrated at night than during the day—on this account nocturnal exposure should be avoided as much as possible.

Old settlers on the West African coast have long recognised the danger of venturing out of doors when the sun is not above the horizon. In the malarious districts of Italy, travellers find the danger of going about at night. The hours immediately preceding sunrise are found to be the most dangerous. The evident cause is, that the malarious vapours which certainly always prefer low altitudes, although not absolutely confined to them, are more concentrated at this period. They have a tendency to keep close to the level of the soil; they are carried upwards by the ascent of the water-vapour during the day, and the condensation accompanying the cold of night carries them down to earth again. Accordingly, the poison is more concentrated during the night. Dependent on this is the fact, often learned by travellers in Italian hotels, that it is safer to sleep at night in a top story than in a lower one; and that when one is obliged to travel at night it is much better to travel on the top of the diligence than inside.

Immersion in cold water is to be avoided as much as possible in hot climates.

It has already been mentioned that wading a river or exposure to a drenching shower in Equatorial Africa is almost invariably followed by fever—the same holds true even of a prolonged cold bath. Accordingly, the rule for bathing should be that the water must not be quite cold, and that the immersion should be short, and followed by a rapid and vigorous rubbing with rough towels. In the case of persons who have already suffered from many attacks of fever, or from dysentery, or congestion or other disease of the liver, or any other of the important viscera, warm bathing should alone be used. Bathing should never be resorted to during the process of digestion.

Whenever an accidental drenching from a tropical shower occurs, or that the traveller has waded, or been accidentally immersed in, a stream or an arm of a lake, he should, as soon as possible, remove all clothing and be thoroughly dried with rough towels. Not only fevers, but the introduction of parasites into the integument, is often a consequence of a plunge into tropical waters.

The quantity and quality of food and of drink should be carefully regulated.

The lassitude which is often so much felt by European residents within the tropics too frequently tempts them to the abuse of alcoholic stimulants and of highly-spiced food, as a means of getting rid of such feelings for the time being. The habit is a most pernicious one, and all inducements in that direction should be resisted from the beginning. Such indulgence is one of the most fruitful causes of the permanent ill-health, which is so often wrongly attributed to the mere residence in the hot climate. There is no doubt that food should be used with greater moderation in hot than in cold climates. Heat-producing articles of diet, such as fats, should be taken in far smaller quantity. The meals should never be heavy—especially during the heat of the day, when the serious mistake of indulging in very liberal luncheons is far too frequently made. Sufficient intervals of time should always separate consecutive meals; even in temperate climes a space of at least five hours should always be allowed between meals, and in tropical regions the period should be increased.

So long as the general health continues to be fairly well preserved, there is no doubt that any over-indulgence in the use of alcoholic stimulants is one of the most fatal errors into which the tropical resident can fall. When not over-worked, or suffering from the prostration consequent upon fever or other illness, hot coffee, tea or cocoa will nearly always be found sufficiently refreshing. But, on the other hand, it must be laid down with corresponding emphasis, that a supply of alcoholic stimulants is one of the most important additions to the traveller's outfit. When exhausted by the fever from which the European resident in the tropics is pretty sure to suffer at one time or many, there is no doubt that the judicious use of stimulants is of all means the most essential in application, and the most efficacious in results. It is not merely that the immediate use may make all the difference between life and death at the time, but may save a constitution from being permanently broken. But in order that these good effects may be obtained in the time of need, it is necessary that the use of alcoholic stimulants should be medicinal, and never looked upon as an ordinary adjunct to the essential dietary. When a course of continued physical or mental exertion has to be maintained for a considerable time, there is no doubt that the use of alcohol in

moderation is highly essential. Of the multitudinous forms in which it is used at home, the purer specimens of whisky and brandy are decidedly to be preferred, and they should always be well diluted. Champagne will also be always found a grateful and a beneficial beverage to the exhausted traveller. On the other hand, the unconcentrated alcoholic preparations, such as beer, porter, claret, &c. will be found to give much less satisfactory results; they are much more highly provocative of gastro-intestinal and hepatic derangements; and are, of course, less easily obtained of really good quality.

The cooking should always be conducted with great care in the tropics; the stomach and liver are less able to bear any extra strain, such as would be induced by the attempted digestion of imperfectly cooked food. Besides, parasites are often introduced with ill-prepared articles of diet.

The use of drinking water must be attended to with great care in all tropical climates. The surrounding luxuriance of animal and vegetable life, which so usually prevails, generally furnishes the water with a larger proportion of impurities than are to be found in corresponding positions in temperate climates, and the accompanying factor of high temperature promotes all sorts of fermentation and molecular decomposition in its chemical constituents. Accordingly, the water of the lakes, streams, and pools of hot countries are extremely impure, and contain the seeds of all kinds of gastro-intestinal diseases. On this account, all water should be filtered and boiled before being used for drinking or cooking purposes. The drinking of very cold water, to which there is often great temptation when one is exhausted by prolonged heat and copious perspiration, should be most carefully avoided. The feeling referred to often induces tropical residents to have recourse to *iced* water, which is always extremely dangerous under such circumstances. The use of copious draughts of water is also a habit to be deprecated: it certainly weakens the muscular energy, and is always rapidly lost by perspiration, which tends to increase the feeling of exhaustion. Hot or cold tea, without milk or sugar, is usually one of the most grateful, and least injurious, of the beverages which can be used by the tropical resident when working or journeying under a hot sun.

In this connexion it should also be remembered that the process of freezing by no means destroys all the pathogenic microbes, so that the fact that the water to be used has been procured by the thawing of ice

by no means guarantees its freedom from disease-producing agents, as many otherwise well-informed persons seem to think. Also, that in other parts of the world, as well as in the tropics, it is often very necessary to use all the above precautions with regard to drinking water on entering an unknown district.

It is hardly necessary to observe that travellers in remote regions, and more especially in tropical climates, are much more exposed to physical ills and diseases than most residents at home, and that they are also more likely to be placed beyond the reach of skilled medical and surgical aid when the latter may be most required. It is especially for the use of the non-professional traveller that the following pages have been written, in which the symptoms and general treatment of the diseases and injuries from which he is most likely to suffer are dealt with in simple, non-technical language.

In recommending the medicinal remedies with which the traveller should be provided before leaving home, I have chosen throughout the tabloid preparations of the well-known firm of Messrs. Burroughs, Wellcome, & Co., as I have found, after a very considerable experience of tropical travel and exposure, which form the very severest tests of the reliability of medicines, that they are the best I know of in constancy and unchangeability of strength, as well as in their extreme portability for purposes of transit.

A.—Medical Diseases.

Cold in the head (coryza), *inflammation of the upper part of the wind-pipe*—the organ of voice or larynx (laryngitis), *inflammation of the branches of the wind-pipe* (bronchitis), *inflammation of the lung* (pneumonia), and *inflammation of the investing membrane of this organ*—the pleura (pleuritis), may be conveniently considered together, forming, as they do, a continuous group of ailments due to exposure to chill, and affecting, as they do, the various sections of the organs of respiration according to the degree of exposure, the general susceptibility of the patient, or the special vulnerability of the organ attacked. When a cold is confined to the head, it can usually be cut short by retiring to bed early, taking a ten-grain dose of Dover's powder (two five-grain tabloids), with hot drinks to promote the perspiration which the action of this drug produces, and the use

of as many additional bed-clothes as can be conveniently borne. Care should, of course, be taken to avoid chill on the following morning. In tropical regions, five grains of quinine (bisulphate tabloid) may be added with advantage to the ordinary dose of Dover's powder.

When the wind-pipe is affected, there is hoarseness of voice, cough, pain in swallowing, and tenderness on pressure over the region of Adam's apple. A similar treatment may be adopted, in addition to which the upper part of the front of the throat should be kept well poulticed for a day or two, and then wrapped up in cotton wool for some days longer.

When *bronchitis* exists, there is a good deal of coughing—at first dry, and afterwards accompanied by frothy expectoration—with a sensation of rawness and tenderness at the upper part of the breast-bone. In the early stage of this condition, half tea-spoonful doses of paregoric elixir (two fifteen-min. tabloids of tinct. camph. co.) will be found very beneficial. The opium tinct. tabloids, of which two to four may be taken every half-hour, will be found an excellent remedy during the first day of the development of bronchitis, and will often effectually cut short an attack.

As even what would appear to be ordinary feverish colds have, in tropical climates, very often a tendency to become intermittent, the use of quinine in addition to the other treatment employed is often very desirable. The tabloids of quinine bisulph., which contain five grains each, can be taken every third hour with the best result.

Pneumonia is always ushered in by severe and prolonged shivering, during which the temperature rises rapidly, and the pulse and respiration are greatly quickened. The face is flushed, the skin feels very hot and peculiarly dry, the patient is prostrated by heavy sickness, and there is a short cough, dry at first, but afterwards there is expectoration of a moderate quantity of viscid, rust-coloured (blood-stained), and almost frothless matter.

A patient attacked with pneumonia should take to bed at once. The chest should be surrounded with a large poultice on the affected side. If the fever is very high, with great restlessness and rapidity of breathing, bleeding often gives more relief than any other treatment. Quinine is decidedly beneficial, a five-grain tabloid of the bisulphate should be given every third hour; in cases where other complications exist, a tabloid of digitalis tinct. should be given every hour for one or two days when the temperature is very high.

Pleurisy is accompanied by a more moderate degree of fever and general sickness than pneumonia; its great characteristic symptom is the "stitch in the side" which always accompanies it. It is also accompanied by a short, dry cough, which the patient tries to restrain as it "catches" in the side, and causes very acute pain. For the same reason the respiration is shallow, as any attempt to draw a deep breath causes extreme suffering.

This is more a disease of cold climates; it is very usually the result of chill following severe exertion. The patient suffers greatly, and, on that account, the most important symptom in the early stage of the disease is the pain. If leeches are procurable, the application of half-a-dozen to the painful region of the chest is always an excellent remedy. After this, five tabloids of the opium tincture should be taken every hour. The movements of the chest during respiration should be checked by carefully-applied adhesive plaster or bandage.

Rheumatism is another disease which very frequently follows exposure to damp cold, and is on that account not so frequent in the tropics as in temperate and cold climates. A decided predisposition to this affection is generally traceable in the persons attacked. It is very often hereditary, and tends to recur in the same individual. On that account it is very necessary that persons with a tendency to this disease should use special precautions. The acute cases are ushered in by shivering, with rise of temperature, and general sickness; while the joints become painful, tender, and afterwards swollen. It agrees with other feverish conditions in the rapid pulse and respiration, constipation, scanty and high-coloured urine, etc., but it differs from most of them in the presence of a profuse and highly acid perspiration, which gives the patient a very characteristic buttermilk-like smell.

The great remedy for acute rheumatism is soda salicylate. Four of the five-grain tabloids of soda salicylate should be taken every third hour. This will nearly always correct the acute symptoms in two or three days. If the symptoms subside sooner, the quantity of the drug should be diminished; if there is a pronounced tendency to delirium the quantity should also be lessened at once. The joints should, at the same time, be kept completely wrapped up in cotton wool, secured with oiled silk and flannel bandages.

Colic.

This is the name given to the well-known severe twisting or griping pains in the abdomen, usually due to irregular development of gas within the intestine, and dependent on constipation or the unhealthy fermentation of some ill-chosen article of diet. Hot turpentine fomentations should be applied to the abdomen, and a turpentine enema will nearly always cut short the symptoms. A full dose of opium should also be given.

Constipation.

This condition is very frequent in tropical climates, where it is associated with torpidity of the liver. It is also very generally met with on board ship. One of the best remedies is the tabloid of cascara comp., of which one may be taken three times a day. In addition to this an occasional dose of a saline purge should always be used, or a large enema of soap and water.

Dysentery.

This disease is essentially a specific inflammation of the lining membrane of the lower segment of the bowel, with a tendency to ulceration. The more severe cases are accompanied by extreme congestion of the liver, which often proceeds to the formation of deep-seated abscess. The most potent causes are bad and insufficient food, impure water, and prolonged chills. General debility and mental anxiety are predisposing causes; and, accordingly, it has frequently proved one of the most terrible scourges of retreating armies.

The disease may, or may not, be ushered in by diarrhœa. The most characteristic symptom in the early stage is the sensation of burning heat and darting pain in the vicinity of the lower orifice of the bowel. This gives rise to the sensation of desire to strain, which continually distresses the patient. The discharge from the bowel at first consists chiefly of gelatinous mucus, which afterwards becomes blood-stained. In bad cases, large quantities of blood are discharged, and even shreds of the mucous membrane of the bowel are detached by ulceration or sloughing, and are passed by stool—giving the evacuation a very offensive

and characteristic odour of decomposing flesh. In addition to this the patient suffers from irregular shooting and griping pains in the abdomen, which is also very tender on pressure.

Ipecacuanha is the specific remedy for acute dysentery. It should be given in very large doses, fifteen to thirty grains (three to six of the five-grain tabloids). The application of a hot poultice to pit of the stomach will often prevent its being brought up again, which it is, otherwise, of course, likely to be. Sometimes opium acts as an effectual corrective to the nausea; so that it will be found that the "Dover's Powder" tabloids will be retained when the others will not be. The dose should be repeated at an interval of about six hours. The abdomen should always be kept covered with poultices as hot as can be borne. Boiled milk and arrowroot, or plantain flour, will form the safest diet during the acute stage. It should be remembered, too, that attention to the diet is of the last importance in this disease. Animal broths should only be used with great caution, if at all. When the dysentery is complicated with malaria, as it very often is in the tropics, quinine should also be given—large doses will often be well borne (three of the five-grain tabloids of quinine bisulphate).

Fever.

The peculiar fevers from which travellers are likely to suffer are more especially those of the type generally known as malarial. I don't propose to discuss the nature of the specific poison which produces these fevers. Two broad divisions of malarial fever are generally recognised: the *intermittent*, and the *remittent*. The former is popularly known as *ague*, and is characterised by the recurrence of definite periods of complete absence of the elevation of temperature. The latter presents well-marked subsidences of temperature; which, however, never descends to the normal standard till the patient is entering upon the stage of convalescence.

A characteristic attack of *ague* is ushered in by a feeling of *cold* running down the spine, the patient feels general malaise, he seems to shrivel up, as the superficial blood-vessels all contract, the lips and finger-tips become livid, the hair stands on end ("goose-skin") and severe pains are felt in the temples and in the loins. During the whole of this stage of apparently violent chilliness the temperature is rapidly rising. As this stage passes

off, the superficial blood-vessels dilate; and, as an immediate consequence, the surface becomes flushed, and the patient feels uncomfortably *hot*. The skin is, however, still dry; but, by-and-by, perspiration commences, which soon becomes very profuse — constituting the *sweating* stage. During this latter stage, the temperature gradually falls till it has reached the normal standard. When the fever has gone, the patient feels weak and exhausted, with a great deal of muscular soreness. If the hot stage is much prolonged, a hypodermic injection of pilocarpine gives relief by inducing sweating.

The attacks sometimes repeat themselves with the greatest regularity. The best treatment is the use of large doses of quinine, given a little before the expected time of attack. The doses which may be borne are sometimes enormous; the present writer has often taken as much as 60 grains at a single dose. The quinine should never be administered during the paroxysm of intermittent fever: it never cuts short the attack; while, on the other hand, it increases the sickness and distress. The patient should, of course, have rest in bad cases; although it is wonderful to observe how well the affected person can go about, and do a good deal of energetic work during an attack of African fever. Every one of the white officers of the Emin Pasha Relief Expedition had, over and over again, the experience of going through a hard day's work with a temperature of between 105° and 106° F., doing 15 or 20 miles march.

A full calomel purge at the beginning of an attack is often very useful. Where a sweating stage occurs, it is of course very desirable to prevent any exposure to chill during, and for some time after, its course. In bad cases of remittent fever, it is very desirable that the patient should be removed, even while the fever is on him, to a higher and drier locality; during the early stage of fever a large dose of opium is invaluable.

In cases of older standing, quinine sometimes appears entirely to fail as a curative agent. In such cases, arsenical preparations are often extremely useful. Two of the 1–50 gr. arsenious acid tabloids may be taken every third hour for a considerable time. It must be remembered that arsenical preparations should never be taken on an empty stomach. Warburg's tincture is also most useful.

Affections of the Liver: Congestion, Abscess.

A large proportion of the cases of "liver" which occur in the tropics are undoubtedly the results of over-stimulation by the excessive use of hot condiments and alcoholic stimulants. There can be no question, however, that the malarial poison affects this organ, and that many of the worst cases are due to its influence; while in every case, the functional weakness of the organ, induced by the action of this mysterious agency, renders it more likely to be affected by the action of stimulants and other agents which would have but a slight deleterious effect had it been in a previously healthy condition.

Congestion of the liver is indicated by a sensation of fulness and dragging under the false ribs on the right side; the organ may, in thin persons, be felt in this position; it is somewhat tender on pressure; there is sometimes pain referred to the right shoulder; usually a little jaundice—most noticeable at the inner corners of the eyes. The patient suffers from lassitude, indigestion, and a bad taste in the mouth.

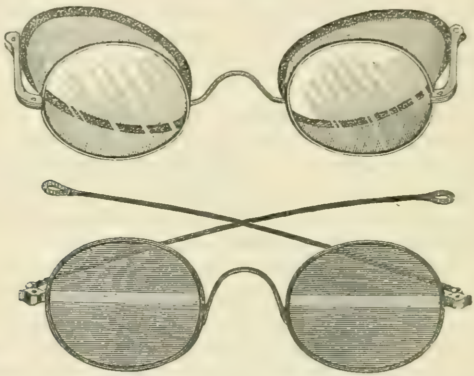
When abscess of the liver exists, the symptoms are sometimes very obscure indeed; but in the well-marked cases there will be night-sweats, wasting, and hectic fever, with its characteristic oscillations of temperature. If fluctuation is felt draw off the fluid with an "aspirator" or puncture.

Acute congestion of the liver should be treated by hot fomentations, and the use of calomel and saline purges. The use of ipecacuanha is also extremely beneficial in acute congestion and inflammation of the organ. Large doses are indicated: a five-grain tabloid may be taken every two hours for the first day, while the pit of the stomach, as well as the surface over the liver, are kept covered with hot poultices. The patient should be allowed absolute rest in all very acute cases. The diet should also be restricted; vegetable food is the safest.

Night Blindness: Snow Blindness.

Night blindness sometimes results from exposure to the glare of the tropical sun—especially if long continued—in the case of persons debilitated by insufficient or bad food. Snow blindness, on the other hand, follows over-stimulation of the retina by the glare from snow, when the eyes have been for a long time exposed to it, either in Arctic regions, or at

altitudes above the snow-line in temperate or tropical zones. Of course the best treatment for all such cases is the preventive one of wearing protective spectacles. Travellers in snowy regions should always be provided with smoked glasses; if these happen to get broken or lost, some opaque substance may be smeared over the surface of an ordinary pair, having a narrow horizontal slit of clear glass—in the Esquimaux fashion, shown in the accompanying illustration. On snow it must



be remembered that the perforated wire gauze sides are essential for protection from the refracted sun's rays. Elastic may be substituted with advantage for the ordinary metallic attachments, between the glasses as well as around the head. In the tropics a veil is sometimes attached to the glasses, and can be worn as a protection from insects and from the blistering of the face which is produced by the sun's heat. Blackening the skin around the eyes, and the adjacent part of the nose, is a good deal employed by natives of high mountain regions in some parts of the world as a preventive treatment of snow blindness; but it is, as will easily be surmised, a very inefficacious one.

Ophthalmia.

Ophthalmia, or *conjunctivitis*, is inflammation of the membrane which covers the front of the eye-ball and the deep surface of the eye-lid. It is

characterised by gritty pain, *i.e.* a feeling as if sand or dust had got under the eye-lid; the affected eye is "blood-shot," and exposure to strong light is intolerable. The eye waters profusely. When severe, it is accompanied by a certain amount of headache, and even general fever. It is often due to cold draughts of air, also to the particles of sand which are always getting into the eyes in sandy regions (as in tropical deserts). It is also produced by the irritation of flies, which swarm in legions about the traveller during so much of his tropical wanderings; and, as the worse forms are undoubtedly highly contagious, flies carry about the germs of the disease from eye to eye.

Careful washing of the eyes, and subsequent application of a solution of borax, cocaine, or zinc, or the use of atropine discs, will be found a satisfactory treatment if the disease has not been too long neglected. In chronic cases skilled assistance will be necessary.

Piles.

This troublesome affection is common in tropical climates, dependent, as it so usually is, on some sluggishness or arrest of the circulation within the liver. Piles are dilatations of the veins in the neighbourhood of the orifice of the lower bowel. These enlargements form painful tumours, which are situated sometimes within, sometimes without, the orifice, and, on that account, are usually distinguished as *internal* and *external*. The former usually give rise to the more serious symptoms, as they often bleed profusely, and leave the patient very weak and anaemic. Both kinds are accompanied by sensations of heat and painful fulness in the part, which are aggravated by movements of every kind. Their early formation is promoted by sedentary habits, and neglect of the bowels.

When the piles are inflamed and acutely painful, leeching is one of the best methods of palliation. The bowels should always be kept free while piles exist; but violent purging must be avoided, as the consequent irritation and straining will cause increased growth of the piles, and an increase of the distressing symptoms accompanying them. In piles of old standing, surgical operation by a competent hand will be found necessary. When relieved by treatment, the patient should study to prevent their recurrence by keeping the bowels extremely regular, taking a fair amount of open-air exercise, and general regular living, with cold water ablution frequently.

Prickly-heat.

This affection is often very troublesome in the tropics. It may sometimes be avoided by attention to the clothing—wearing light linen or cotton garments instead of flannel, which can be done when the temperature is equable. The annoying heat and itching are relieved by the application of carbolic solution to the skin (about a table-spoonful of carbolic acid to a pint of water). A good saline purge should always be administered at the beginning of an attack.

Ring-worm.

This disease is infectious, as it is propagated by spores. These spores cut into the hair close to the skin, so that it becomes brittle, and breaks off near the surface. The hairs close to the affected spots should be plucked out one by one, so as to isolate it, and the part should then be frequently dressed with strong carbolic lotion, painted with liniment of iodine, or strong solution of corrosive sublimate.

Sea-Sickness.

As is well known, some travellers are martyrs to this extremely distressing affection. Others suffer a little at first, but the symptoms wear off when they have become accustomed to the motion of the vessel. Some do not suffer at all. A great deal depends then on the nervous constitution of the patient. As every traveller from the British Isles has first to encounter the trials of the surrounding ocean, it is, of course, very desirable that he should be prepared to meet this early difficulty. I have usually found that the best preventive preparation of the system consists in having a saline purge administered on the day before the intended embarkation, and a comfortable meal immediately before going on board. A cup of strong tea, or strong black coffee, taken after starting, is a very efficacious preventive remedy in many cases. When symptoms threaten, the horizontal position should be assumed at once, with the head as low as possible; a hot jar to the feet, and a hot poultice, or sinapism, to the pit of the stomach, will then check the progress in most cases. On this account, persons who are specially prone to sea-sickness should, on getting on board, retire at once to their respective berths. A tight belt is sometimes useful.

Sleeplessness.

This is often a distressing symptom, especially in the case of persons already weakened by malarial and other affections, who are, indeed, the most likely to suffer from it. It is also produced by excessive heat or cold, the irritation of mosquito bites, the annoyances of other insects and parasites, the abuse of tea and coffee, and, of course, indigestion. Coldness of the feet is a potent cause. On this account it will often be found that strong kneading of the feet and legs often acts as a powerful sedative. The application of a hot-water bottle to the feet sometimes acts like a charm in causing sleep. When there is troublesome indigestion, the application of a hot poultice to the stomach has a similar soothing effect. Opium, bromides, chloral and sulphonal are useful.

Sunstroke.

This deadly affection is by no means characteristic of sub-tropical climates. The present writer has seen more cases by far in England than in Africa, during nearly nine years' experience of the vicissitudes of the "Dark Continent." It is said to be decidedly rare in the insular regions of the tropics, as in Jamaica, Ceylon, etc., and the progress of the Emin and Gordon Relief Expeditions was singularly free from it. It must always be looked out for when the surrounding temperature exceeds that of the surface of the body, 98·4 F. It may be produced either by direct exposure to the sun's rays, or by the influence of a super-heated atmosphere. Sometimes the patient falls down suddenly. In a larger proportion of cases, premonitory symptoms are present: giddiness, sickness of stomach, peculiar heat and dryness of the skin, blood-shot eyes, and frequent micturition. In such cases, the attack can, probably in every instance, be warded off by prompt treatment. The patient should at once be drenched all over, especially on the head and along the spine, with cold water, and this treatment should be kept up for a considerable time. A large dose of calomel should also be placed at the back of the tongue, or better, in very urgent cases, a turpentine enema should be given as quickly as possible. The patient can then be made comfortable in bed, with cold wet cloths wrapped around the head and adjusted along the spine. They should be frequently changed and wetted, so as to prevent them from getting warm, and this treatment should be persisted in till the patient has been roused.

Parasites.

Worms are nearly always introduced into the system through the media of unfiltered water, or imperfectly-cooked food. The same may be said of other internal parasites. There are exceptions, as we shall see later on.

Intestinal worms are divided into two great classes: the *tape* worm and the *round* worm. Each of them gives rise to a series of intestinal derangements, but the diagnosis of their existence can hardly ever be made with certainty except when a part, or the whole, of a worm has been passed with the evacuations from the bowels. Accordingly, the great preventive treatment, obviously, is the careful adoption of proper precautions with regard to food and drink. For curative treatment, the liquid extract of male fern (thirty drops beaten up with yolk of egg), or large doses of turpentine (one to two fluid ounces—two fluid ounces being equal to a wineglassful), will be found effective. For the round worm, a full dose of santonin (six grains for an adult), followed by a purgative, is always efficacious.

The *guinea worm*, which is a very common and very troublesome parasite in the countries around the Red Sea, is also introduced with food or drink into the alimentary canal, but makes its way to the subcutaneous connective tissue, which is the only place in which it develops. It gives rise to very troublesome sores, and can be removed only by a careful process of extraction, for which a skilled hand is always necessary.

Care of infants and children.

In the care of young children, the first thing to be thought of in foreign climes, as at home, is the necessity for warm covering; the second is the administration of proper food, and at regular intervals. The more active tissue-changes accompanying the growth of children is accompanied by the evolution of larger proportional quantities of heat than in the adult. The greater proportion of surface to persons in early life favours the dissipation of this heat by radiation. The heat-regulating mechanism is not so well developed in very early life, and, accordingly, a slight disturbance of the system causes a greater proportion of febrile disturbance. The pulse is also disproportionately quickened in the

illnesses of childhood. Gastric disorders are also very easily induced at this period of life, as the digestive organs are very delicate, and their functions are easily deranged. On this account, the clothing, as well as the diet, of young children should always be attended to with great care. It is a terrible mistake to think, as many people seem to do, that rough and ready treatment in very early life will help to make young people more hardy afterwards. Exceptionally robust constitutions may resist the effects of these mistaken notions, but there is no doubt that the seeds of chronic disease and of permanent delicacy of constitution are often laid in this absurd management of childhood. Bare legs, bare necks, and arms are too often displayed in childhood, and invite the future development of rheumatic and tubercular affections. These parts should always be protected—in the varying seasons, and in different climates, according to temperature and surroundings—with thicker or thinner clothing, as the requirements of the cases demand.

The abdominal organs are, as is well known, extremely susceptible to the effects of extremes of temperature, and of local irritation, in childhood. On this account, a flannel binder should always be worn by children in sub-tropical regions, where such influences are most likely to be felt. The effects of chill are severely felt in childhood, but warm drinks, rest, equable temperature, gentle purgatives, and subsequent careful feeding will nearly always suffice to neutralise them.

The nervous system is also extremely susceptible in childhood. The effects of reflex irritation due to some local cause, such as the cutting of a tooth, or the presence of intestinal worms, are such as often to give rise to most alarming symptoms, such as convulsions, delirium, or paralysis. The onset of fever in early childhood is also frequently marked by a severe attack of convulsions. In estimating the severity of febrile symptoms in childhood, too much attention should not be attached to the rate of the pulse, which is very easily quickened to an extreme degree at this early stage of life.

At the onset of any high fever in children, one of the best initial treatments is the use of the hot pack. A blanket should be wrung out of water as warm as can be borne without positive discomfort, and the child's body may be wrapped in it, and the ends turned up and pinned, so that no current of air can circulate between it and the skin.

When purgation is required, mild doses of castor oil, of fluid magnesia,

or of liquorice powder, can always be used with advantage. Mercurials are often abused in childhood, and should rarely be employed without skilled advice. Opium is dangerous. A generous diet, with fresh air, will prevent the development of *rickets*, which leaves such painful deformity in the unhappy subjects who are affected by it. It is very generally found in children who have been brought up on artificial foods and milk. The milk of very delicate mothers will also predispose to its development. Fresh air, with a well-selected and varied diet, including the important factors of good cream and some cod liver oil, will be nearly always found sufficient to arrest the disease, if it has not already proceeded too far.

The distressing affection known as *spasmodic croup* is specially common among rickety children. It should be treated by a warm bath, the use of a full emetic, inhalation of hot steam, application of hot sponges to the throat, and, of course, rest in bed. Repeated doses of chloral have a good effect afterwards.

Convulsions are also treated by use of the warm bath, and sedatives, such as a mixture containing chloral, with bromide of sodium or ammonium. It must be remembered that disordered bowels, the presence of intestinal worms, and the onset of fevers, are the commonest causes of convulsions during childhood.

During *teething*, great care must be taken of delicate children. They are frequently attacked by convulsions—sometimes by reflex paralysis. These can, however, be nearly always checked by regular use of laxatives, and of the warm bath. Lancing of the gums must be resorted to when necessary.

Diarrhœa is a common affection of childhood, and usually requires a treatment beginning with the use of a purgative, as it is very generally dependent on the presence of some irritating substances in the bowels.

Thrush is nearly always due to some derangement of the stomach or bowels. Attention to diet, following the administration of a castor oil purgative, and the application of borax and honey to the interior of the mouth, will be found effective treatment in almost every case.

Worms are often very troublesome, and especially in the tropics, where intestinal parasites are oftener found than in temperate climates. They give rise to intestinal derangements, disorders of appetite, flatulence, griping pains, diarrhœa, restlessness, grinding of the teeth during sleep,

and other misleading symptoms which have been already referred to, such as convulsions and paralysis. Two kinds of worms are comparatively frequent in children: the *round* worm, which is found high up in the bowel, and the *thread* worm, which is always found near the lower orifice. Santonin is an effective remedy for the former; the latter is best treated by an injection of some bitter fluid, such as infusion of quassia.

Wasting in children is generally associated with chronic diarrhœa; and is, very usually, connected with an unhealthy condition of the intestinal glands. The limbs become extremely thin and worn, and the abdomen tumid to an enormous degree. In such cases, great care must, of course, be taken with the diet. Cow's milk is generally very badly digested in such cases. Starchy foods, being fermentable, also disagree very much. Condensed milk, diluted with thin, freshly-made barley-water, is much easier of digestion. If cow's milk must be used, it should always be diluted with water and given warm. The addition of lime-water, about one-third the bulk, is often very useful for delicate children—especially where a tendency to rickets is threatened.

B.—Surgical Diseases and Injuries.

Bleeding (Hæmorrhage).

Serious bleeding is of two kinds: *arterial* and *venous*. Arteries are the vessels which convey the blood from the heart away to the tissues. When one of them is divided, the blood, which is bright red in colour, escapes in *jets*, with considerable force and velocity; so that, if the wounded artery is a large one, there is great danger of immediate death. On the other hand, when a vein is divided, dark-coloured blood flows out quietly—it never spouts to a distance. The veins are the vessels which convey the blood back to the heart from the tissues: they are connected with the arteries by microscopic channels called capillaries. *Bleeding from the capillaries* is very rarely at all dangerous.

When serious bleeding occurs, the patient should be at once placed in the horizontal position, and pressure applied to the bleeding point. When an artery is wounded, pressure should be applied to the bleeding vessel on the side next the heart; when a vein, it should be applied away from the heart. The reason is obvious, if the direction of the blood

current is remembered. If the bleeding be from a puncture or a small incision, direct pressure with the finger, and subsequent application of pads carefully bandaged in position, is the best that can be done, till the arrival of skilled surgical aid. Before this can be procured, continuous pressure may be absolutely necessary: will inevitably be, indeed, except some special apparatus is at hand. If there are several persons present to assist, the pressure can be taken by each in turn, as the exertion of keeping it up, although apparently slight, is well known by those who have had to practise it to be extremely tiring. If no other means are procurable, the application of a tight bandage (in case of wound of a limb) above the seat of injury will be an effective check to profuse arterial bleeding. Venous bleeding can nearly always be readily checked by local pressure. If an elastic bandage be carefully applied it will arrest any hæmorrhage from a wounded limb. If a piece of india rubber tubing can be procured and tightly applied above the seat of injury, in case of wound of a limb, it will be found an effective method of arresting the bleeding. The oldest form of tourniquet consisted in tying a handkerchief around a wounded limb—then inserting one end of a stick between the handkerchief and the skin, and twisting forcibly. The effect is obvious, and will certainly prevent fatal hæmorrhage if done in time. Arterial bleeding from the palm is very troublesome. It may be treated—till skilled assistance can be procured—by bandaging the fingers, placing a rounded pad in the palm, on which the fingers are then closed; the bandage is then carried up to the elbow, when the joint is flexed and secured in that position by the bandage. The arm should then be supported in a sling.

In the case of wounds high up in the arm, or in the arm-pit itself, the subclavian artery must be controlled by pressure against the first rib. This is applied from above the collar-bone. In the case of serious wounds high up in the lower limb, the femoral artery can always be secured by pressure in the middle of the fold of the groin. In the case of the leg below the knee, the latter joint should be firmly bent, and the limb well bandaged from below upwards. A pad should be placed on the bleeding point, and the knee firmly secured in the flexed position by the bandage.

Stimulants should be avoided after hæmorrhage, as they increase the activity of heart, and tend to renew the bleeding.

Blisters on the feet.

These are generally caused by creases in the socks, or some roughness on the inside of the boot, during a long walk; accordingly, the prevention is obvious and easy. Great care should be used in the selection of boots and socks, as blisters are very painful and annoying. When they have been formed, they should be pricked—to let out the fluid—and good adhesive plaster applied, which will protect the raw surface effectually. When the feet are naturally tender, and prone to form blisters on slight provocation, soaking them for some time in tepid salt and water, before putting on the socks in the morning, has a very good effect. Rubbing the insides of the socks with soft soap is also a very good preventive. Knitted socks are the best.

For tender feet, of course, very comfortably fitting boots should always be carefully selected before travelling. Broad and low heels, and elevated and broad toe-caps are desirable features. It should also be remembered that it is a decided mistake to wear *too large* boots for long walks.

Boils and carbuncles.

These well-known affections differ in degree rather than in kind. The carbuncle is an exaggerated boil; it tends to spread considerably in some cases, and is indicative of a feebler state of the general system. On this account, the use of generous diet and stimulants is indicated where a carbuncle forms. Both require protection and poulticing. When the carbuncle is extremely tense and painful, a free incision along the length of its greatest diameter, or the destruction of the skin over its central part by means of caustic potash, will be found the most effective means of relief.

For boils, poulticing, free purgation, and a light, well-chosen diet are the only general remedies that need be employed, also a small incision to evacuate pus if necessary.

Bruises.

A bruise, when recent, should be treated with a cold lotion, irrigation with cold water, or application of wet cloths—very porous and often changed—or a more carefully-prepared evaporating lotion.

Burns.

Where an extensive burn or scald has occurred, the clothing of the affected part should be removed by cutting, so as to cause as little irritation of the burnt surface as possible. Lint (or rags of some kind, if lint cannot be procured) should be thoroughly moistened with a mixture of equal parts of olive oil and lime-water, and applied to the injured surface. If this dressing is not to be had, flour or powdered starch should be dredged over the surface till completely covered, and then protected from being rubbed off.

Chilblains and frost-bites.

Chilblains are usually found on the fingers or toes, after exposure to severe cold, when tightly compressed—by the gloves or boots, as the case may be. Some persons are specially liable; and the best way to *promote* their formation certainly is to toast the semi-frozen fingers or toes, at a fire or stove, before the circulation has been re-established. Similar conditions, more aggravated and prolonged, lead to the development of *frost-bite.*

Chilblains are checked in the beginning by painting with tincture of iodine or strong solution of nitrate of silver. When threatened, the part should be well rubbed with snow, or with camphorated spirit. Ulcerated chilblains can be effectively treated with boracic ointment spread on lint.

Frost-bite should be treated in the beginning by *very rigorous friction* with snow or pounded ice. The affected parts should be then well wrapped with cloths wet with cold water. It is extremely dangerous to bring the frozen part near a fire. Afterwards, the part should be wrapped in cotton wool. If the case is a bad one, or injudiciously treated, gangrene always follows; if this is extensive, amputation will be necessary.

Concussion of the brain.

This term is given to the condition accompanying the partial suspension of the functions of the brain produced by the severe shaking of its substance by a fall or blow. The patient lies in a semi-unconscious condition, with cold, clammy skin, and very feeble pulse and breathing. He

can be somewhat roused by shouting into his ear, and cries out when painful applications are made, but quickly relapses into insensibility. In these cases, a large turpentine enema should be given at once, and a full dose of calomel or croton oil (in a little mass of butter) placed on the back of the tongue, when it will be swallowed by the reflex action of the muscles. When reaction sets in, the head should be kept cold, with an evaporating lotion or an ice bag, and the bowels still kept very free.

Stimulants should be avoided in cases of concussion of the brain; they tend to cause too violent reaction, which would be followed by inflammation of the brain and its membranes.

Drowning.

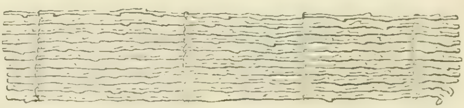
It must be remembered that, in cases of submersion in water, the great object is to restore the action of breathing. If the heart's action has not completely stopped, this can always be done by skilful treatment. In order to succeed, it is absolutely necessary to quickly clear out the air passages. For this purpose, it is well to place the patient in such a position that the head is lower than the body, and the body itself on an inclined plane, sloping downwards towards the head. In this position the water will tend to drain from the air passages. The tongue should instantly be drawn forward, and the mouth and nostrils cleared of froth and mucus as completely as possible. The patient may be first placed on his side, with the lower arm raised to the level of the face. The other arm should then be firmly grasped between the elbow and shoulder, and with it the patient should be drawn round so as to lie on his back, the arm being at the same time firmly drawn above the patient's head. He should be then rolled round to his face, during which movement the arm must be brought down to the patient's side, and forcibly pressed against it, while the patient is on his face. After some time, firm pressure should be made by the knees against the back, between the shoulder-blades. This series of movements should occupy a time of between three and four seconds, and must be regularly repeated for about five minutes. At the end of this time, a great part of the water will have drained away through the mouth and nostrils. If breathing has not then been re-established, the patient should be rolled on to his back, and the operator, standing behind the head, should grasp the arms above the elbow, and raise them

slowly above the head as far as they can be drawn, hold them there for a second or so, and slowly depress them to the sides. When in contact with the sides, they should be pressed as firmly as possible against the chest. The same series of movements should then be repeated about twenty times per minute, as in the other case. This manipulation should be continued for *even several hours*, so as to establish respiration if possible.

Fractures and dislocations.

The commonest of all fractures is that of the *collar-bone*. The bones of the limbs, and the ribs, are also frequently broken. The nature of the injury is known by the mobility of the fragments, and the *grating* (which may be both *felt* and *heard*) when the fragments are moved against one another. When a fracture occurs, the parts should be brought back to their natural position as soon as possible, and firmly retained in that position by means of splints and bandages. In case of fractures of the arm-bone, and of the thigh-bone, there is a great tendency to *shortening* of the limb by the contraction of the muscles around the broken bone, which, if not carefully counteracted, causes *over-riding* of the broken extremities.

Splints can be extemporised by cutting pieces of board of moderate thickness into appropriate lengths. If boards are not procurable, rods or straight sticks can be cut into corresponding lengths, and secured



together with strings, as shown in the figure. In case of fracture of the thigh-bone permanent extension must be kept up, otherwise the limb will be shortened.

If no other supports for a broken limb are procurable, considerable protection will be afforded by filling stockings or shirt sleeves with sand or earth, and placing them on either side as the patient is lying down. Bundles of rushes, strong reeds, or iron wires tied together, are also sometimes employed.

Fracture of the *collar-bone* should be treated by placing a large

pyramidal pad, about six inches long by three in thickness at the *upper* end, in the arm-pit, and securing it with tapes tied over the opposite shoulder. The elbow should then be brought forwards, and raised and well supported by a broad triangular bandage, or handkerchief, used as a sling, and with the ends tied over the opposite shoulder, at the root of the neck. A flannel roller can then be passed loosely round the chest several times, so as to secure the arm from accidental movements.

Fracture of the ribs should be treated by wrapping a flannel roller around the chest pretty tightly, so as to limit the movements of respiration, which are very painful. It should be secured by stitching, and the upper turns should be fixed by broad tapes passed over the shoulders and firmly stitched. Firm strapping of the side with adhesive plaster is still better, and should be used if possible.

Fractures of the upper arm may be treated by the application of several narrow splints, well padded, and supported in position by a bandage carried from the fingers to the arm-pit. Care must be taken that the splints on the inner side do not chafe the folds of the axilla. The hand and wrist should then be supported in a sling, but the elbow must be allowed to hang free.

Fractures between the wrist and elbow must be treated by two splints, each *wider than* the limb. One is placed behind; the other in front. The former reaches down to the finger-tips, the other not beyond the palm. In securing them in position the thumb must be placed upwards, and the whole limb, from elbow to wrist, supported in a sling, with the hand a little above the level of the elbow. Too much pressure must never be used in adjusting the bandages, and these should always include the fingers.

Fractures of the lower limb are much more serious; they require the patient to keep lying down till union has been effected, and they are more likely to lead to permanent deformity if not very carefully treated. Those of the *thigh* invariably produce shortening and permanent lameness, if not treated by a skilled surgeon.

Fractures of the leg can usually be fairly well adjusted by extending the limb so as to remove the deformity, applying a splint on each side, long enough to reach from the knee to a little below the sole of the foot, and bandaging them in such a position as to have the great toe in a line with the inner border of the knee-cap. It is not, comparatively speaking, so

hard to keep the limb in position, as in other fractures; and, accordingly, very crude apparatus, *e.g.* an umbrella on each side, will often be found fairly serviceable in the absence of properly-prepared splints. They may also be tolerably well supported by thick pads on each side formed of a great number of layers of cloth of some kind (calico, etc.) and tied in that position. When the accident occurs in the open air, the injured limb should be tied to the sound one, till the patient is brought to a place of security.

Compound fractures, i.e. fractures in which the broken ends are exposed by a wound, or actually protruding through the skin, are very serious injuries when occurring beyond the reach of skilled assistance. In such cases, all dirt should be removed from the wound by syringing with tepid water, to which a little weak carbolic solution should afterwards be added, if procurable. The parts must then be adjusted by very careful extension, and pressure, if the fragments protrude. Splints are then applied as in other cases, but the bandage must not be carried over the opening in the skin. This should be covered by a carbolized pad, and kept loosely in place by a piece of flannel roller, so that there shall be no obstacle to the escape of discharges.

Dislocations can hardly be discussed here with much advantage, as they nearly always require skilled aid. The most frequent is that of the shoulder, which is generally easy to diagnose. The patient cannot raise his hand to his head, and the *joint is rigid* when anybody attempts to move it for him. This distinguishes the injury from a fracture. The shoulder is flattened, and the elbow sticks out from the side; while the length of the limb is usually somewhat increased. The reduction can generally be effected by placing the patient lying down, inserting the unbooted heel of the foot of the *same* side in the arm-pit, and drawing the arm firmly and steadily downwards, while the heel is made to press against the head of the bone in the outward direction. Dislocation of the bones of the fore-arm backwards at the elbow joint is pretty common, and can usually be reduced by placing the knee in front of the patient's elbow, and making firm traction on the forearm—which is at the same time flexed a little around the operator's knee. The patient can be kept sitting in a chair while this is done, and the operator can get his knee into the required position by placing his foot on the side of the chair.

Parasites.

The *jigger* (*Pulex penetrans*) is one of the parasitic pests of tropical climates, and often gives a great deal of annoyance. It lodges in the skin, in which it burrows, and establishes so firm a hold that it must be picked out with a pointed instrument. After it has been dislodged, the part should be well smeared with carbolic oil.

Ticks also give rise to a great deal of trouble by burrowing in the skin, where they produce intense itching and irritation. They are sometimes found in the nostrils. They should be similarly treated.

Leeches abound in the long grass of certain tropical districts—notably of India and Ceylon. They attach themselves to the skin, and have often been known even to creep into the nostrils, where their bites cause considerable loss of blood. They are best removed by salt and water—applied to the surface, or injected into the nostrils, as the case may be.

Fleas and *bugs* may be kept at a respectful distance by the use of "Keating's Insect Powder."

Mosquitos are very abundant in many sub-tropical countries. They must be warded off by the use of netting, as already described.

Midges can be dispersed by smoke.

Rupture.

A rupture is a protrusion of a portion of the intestine under the skin, and is usually found in the groin. It is generally reducible, *i.e.* it can be pushed back into the abdomen. It reappears when the pressure is removed, especially if the patient is asked to cough. When reduced, a properly fitting truss should be applied, and always worn during the day. It can be taken off at night, *after* lying down; it should be again adjusted in the morning, while the patient is still lying.

The great danger of rupture is that it may become *strangulated*. This occurs when the bowels are neglected, or when a large portion of the intestine is suddenly forced out by some severe exertion. If unrelieved, this complication is always fatal. The existence of strangulation is known by local pain and tenderness, development of severe colicky pains in the abdomen (especially about the navel), vomiting, hiccough, and symptoms of collapse. When this condition is observed, the patient's hips should

be raised, by supporting them with pillows till higher than the head, and the tumour should be gently kneaded and pressed with the view of getting back the protruded intestine. The treatment is considerably aided by immersing the patient in a warm bath, and giving a full dose of opium—about thirty or forty drops of the tincture, or in tabloid form. Placing ice around the tumour for half an hour or so is often very effective. If these means fail, surgical aid is absolutely necessary.

Snake-bite.

Provision should be made against snake-bites by wearing stout gaiters. Bites of poisonous snakes are generally recognisable by the fact that the fangs make well-defined circular punctures, while the other teeth make only minute scratches. In the case of sea-snakes, which are generally very venemous, the fangs are very small, so that this distinction is not always available.

Sir Joseph Fayrer recommends the following treatment for snake-bites: "Apply at once a ligature or ligatures, at intervals of a few inches, as tight as you can possibly tie them, and tighten the one nearest to the wound by twisting it with a stick or other such agent. Scarify the wound, and let it bleed freely. Apply either a hot iron or a live coal, or explode some gunpowder on the spot, or apply either carbolic acid or some mineral acid or caustic. Let the patient suck the wound whilst you are getting the caustic ready, or if anyone else will run the risk, let him do it.

"If the bite be on a toe or finger, especially if the snake has been recognised as a deadly one, either completely excise, or immediately amputate at the next joint. If the bite be on another part, where a ligature cannot be applied, or indeed if it be on the limbs above the toes or fingers, cut the part out at once completely.

"Let the patient be quiet. Do not fatigue him by exertion. Give eau-de-luce or sal-volatile, or carbonate of ammonia, or, even better than these, hot spirits and water. There is no occasion to intoxicate the person, but give it freely, and at frequent intervals."

Bites from jackals should be treated on the same principles as those above recommended for snake-bite, as they are sometimes followed by hydrophobia.

Sprains.

These usually occur at the ankle joint. The affected joint should always be raised on pillows, and treated with cold evaporating lotions —thin cloths moistened with cold water and frequently changed, if there are no other remedies at hand. If inflammation be developed, warm fomentations will be found more soothing. Leeching may also be necessary, and free purgation has always a good effect. The troublesome stiffness which often remains is best treated by friction and kneading with the hand. This hand-friction will be found very beneficial, if well applied at the moment of the occurrence of the injury; but, if inflammation has had time to develop, it should not be attempted till this has subsided.

Ulcers.

Ulcers are often very troublesome in tropical climates. They occur usually on the limbs, and especially on the lower limbs, where they often spread from the most trifling abrasion of the skin, caused by a puncture or a scratch, or by the bite of some parasitic insect. Their spreading is, of course, greatly promoted by exposure to the sun's heat, the rubbing of the clothes—or of foreign bodies with which they may come into contact. Want of sufficient nitrogenous food is also a potent factor in the rapid development of large ulcers.

When the ulcer can be protected, and rest can be given to the affected part, a simple dressing of zinc ointment, ointment of boracic acid, or iodoform is usually effective. When the ulcer is deep and large, it may be stimulated to healing by the application of lint or cotton-wool, moistened with carbolic acid (one part of carbolic acid to twenty parts of oil). In the huge gangrenous ulcers of which I have had to treat an enormous number in Equatorial Africa, I have found nothing so effective in checking their progress as the application of pure carbolic acid to the edges and base. If very large, the whole surface should not be so treated at once. Afterwards, the dressings above mentioned will suffice, if rest and generous diet can be procured.

Wounds.

Slight, clean-cut wounds are best treated by bringing the edges together, and securing them in contact by means of strips of adhesive plaster carefully applied, and then brushed with flexible collodion. If there happen to be any dirt, or particles of any kind, engaged in the wound, they should always be removed previously by very careful washing. A weak carbolic solution should then be applied before the parts are secured in position. If there be much bleeding, it must always be checked before the wound is closed. The means for doing this have been described under the head of "Bleeding." In cases of lacerated wounds produced by the bites or gorings of wild animals, and in cases of gun-shot wounds, great pains should always be taken in washing the parts out thoroughly with carbolized water before bringing the edges together. In such cases, stitches will be required to keep them in position. Every shred of skin should be preserved with the greatest care.

In cases where there is much bruising, a good deal of inflammation is likely to follow; and it is always useful, if the patient has not been weakened by loss of blood, to administer a full saline purge. Bruises without much breach of surface should be treated at first with cold lotions; when inflammation sets in, poultices will be required.

In all cases of deep wounds, it is well to have all instruments, the operator's and attendants' hands, and all dressings applied, well soaked in carbolic solution, about one of carbolic acid to twenty of water or oil; or in a solution of perchloride of mercury, 1 in 2000 strength.

Rules for the Preservation of Health in the Tropics.

(*From 'Experiences in Equatorial Africa,' by* T. H. Parke.)

Water.—All drinking-water, no matter how sparkling and pure, should be invariably boiled to insure its freedom from dangerous constituents. Cold weak tea, without sugar or milk, is best for the march. Water should always be drawn from up stream, and from the centre if possible. Two grains of permanganate of potash to the quart purifies water. If muddy, use alum.

Sun.—No precautions can be too great for protecting the head from

the direct rays of the sun. The use of a proper head-dress and umbrella, also a spinal pad for morning and evening sun, is judicious.

Chills, draughts, sitting in damp clothes, especially when heated after violent exercise and copious perspiration, also cooling of the body suddenly in any way, are certain to be followed by fever.

Clothing.—The bodily temperature should be kept as equable as possible. Loosely-fitting woollen clothes are preferable. Light *kămūr-bănd* should be worn day and night. On halting after a march put on a wrapper so as to cool gradually. Get under cover and change, if possible.

Sleep as far as possible off the ground, and always under mosquito curtains at night.

Diet should be plain: meat, fish, vegetables, well-boiled, fruit, rice, and cereals.

Alcohol habitually, especially during the day, is most dangerous; medicinally, on occasions, it is useful.

Tub in the early morning, or at the end of a march, before cooling, never while digestion is going on, and always tepid if possible.

Camp.—Select highland plateau near water supply. Don't disturb the soil. Avoid ravines. Never to leeward of a swamp, unless separated by a belt of trees or a river. Site of latrine should be selected immediately on halting, and covered with a hurdle and sods so as to exclude flies, as they convey blood poison—leaving only a few openings, each about one foot square. Directly tent is pitched hoe a gutter close to the walls in case of rain.

Cleanliness.—Hair should be cut short.

List of Useful Articles.

(*From 'Guide to Health in Africa,' by* T. H. Parke.)

For One Person to take on an Expedition, calculated to last Two Years, and making Four Men's Loads not exceeding Sixty Pounds each.

Tent, measuring seven feet every way, two and a half feet walls, with poles, and fly made from "green rot-proof" canvas; pole-strap, mallet, twelve long galvanised pegs; not to exceed 60 lbs. in weight. The

"Tortoise" is the best design for a large party. (Benjamin Edgington, London.)

Valise, made from strong waterproof canvas, to hold "Parke Africa bedstead," folding armchair (brass fittings), hair mattress, bell-shape mosquito curtain, with the apex suspended from a hook, fine gauze to make a few cylindrical veils for keeping off flies, etc.; two *long* blankets; waterproof ground sheet, about six feet by five feet, so as to improvise a *Tente D'Abri* if required; portable india-rubber bath, and basin; small down pillow, with six washing covers, also clothes packed into valise pillow. Not to exceed 60 lbs. in weight. (Ross & Co., Elliss Quay, Dublin.)

Canteen, containing three circular steel cooking-pots, nested, having moveable handles; one coffee-grinder, one mincer, one gridiron, and one ladle, with moveable handles; three enamelled plates, shaped like saucers, to fit one within the other; one hot water plate; knife, fork, and spoons (tea, salt, and soup); three pudding-tins, nested; enamelled teapot, and kettle, one wicker-covered delf teapot, and cup and saucer; three enamelled goblets, containing about a pint each, nested; tins lined with glass for salt, pepper, mustard, tea, coffee. *Saccharine* tabloids, grs. $\frac{1}{2}$, most excellent substitute for sugar. The whole contained in galvanised bucket, useful for drawing water, and covered by a lid which can be utilised as a frying-pan. (Silver & Co., London.)

Box, portmanteau, or *trunk*, tin Japanned, air-tight, oblong in shape, *or* solid leather, *or* basket-work covered with pig-skin, and lined with zinc, to contain books (*e.g.* Bible, *Hints*, large 'Whitaker,' &c.), papers, waterproof envelopes, "toilet paper," ink in pellets, pencils, maps, ink-eraser, stylo pen, gold nibs, sketching materials, matches in luminous boxes, clothes, camphor blocks to keep away insects, etc. A waterproof canvas kit-bag is most useful for clothes only. When packed not to exceed 60 lbs. in weight.

Head-dress, Helmet, army regulation, with puggaree and curtain; night-cap, and soft cap (deerstalker). (Hawkes, London.)

Water-bottle, ebonite, covered with felt, to hold one quart.

Lantern, "Beresford" folding, for oil or candles. (Silver & Co., London.)

Belt, "Colonial" leather waist, with strap over right shoulder, sheath for *unclasped* knife, holster for light revolver, and small pouch, con-

taining ammunition, a flint and steel, bi-convex burning glass, and alarm whistle on swivels.

Hammock, portable field, and, made of cord, useful to sleep in or for transport.

Filter, pocket asbestos or charcoal.

Umbrella, with three spare covers (green).

Knife, pocket, skeleton, containing one blade, corkscrew, tin-opener, champagne opener (useful to open boxes, etc.), screw-driver, gimlet, tweezers, brad-awl.

Boots: brown shooting, four pairs; three pairs of Veldtschoons: the former to be smeared with dubbing. Spare laces and a pair of boot-trees.

Leggings, leather, one pair reaching to the knee, and one short pair merely to cover the top of the boot.

Pyjamas, silk and wool, with feet to keep out insects, six suits.

Waterproof coat, warm overcoat and one knitted jersey.

Knickerbockers, woollen material three pairs, to be loose, and securely fastened by buckle and strap beneath the knee to prevent insects getting up; one pair of moleskin knickerbocker-breeches for riding.

Drawers, calico, short and loose, half-dozen.

Stockings: knitted, shooting, six pairs; socks, six pairs.

Waistcoat, chamois leather, buttoning to the throat.

Tennis suits, flannel, for lounging in camp, two.

Putties, light woollen material, in fancy colours, two pairs.

Shirts, silk and wool, well shrunken, and loose about the neck, one dozen.

Vests, light silk, six.

Gloves, leather gauntlet, three pairs.

Kămārbănd, silk, two.

Handkerchiefs, red silk, two dozen.

Towels, two bath and six small.

Holdall, containing hair, shaving, and tooth brushes, scissors, razors (two) with strop, comb, soap, sponge, and looking-glass.

Housewife, for needles of various sizes, bodkins, thread, buttons, palm and sail needles, tape.

Napkins, table, one dozen.

Compass, pocket magnetic.

Field-glasses, one pair.

Fish-hooks of various sizes, with line and baits.

Flea-powder, two tins.

Baking-powder, to make bread rise.

Medicines, small pocket-case, in tabloid form. (Burroughs, Wellcome & Co., London.)

Goggles, green colour, two pairs.

Trap, American wire, for catching birds, rats, etc.

Circular spring, for weighing.

Tape measure.

Haversack, for carrying luncheon, etc.

Tools, and spare screws fitted in small leather hand-case.

Extras: Arrowroot, sago, beef tea, "Liebig," three tins of each; brandy, two bottles; curry-powder, anchovy paste, Erbswurst, custard-powder, "composition" foods, celery salt, etc.

Transport.

The prospective traveller should give attention to the ways and means by which those debilitated by sickness, or rendered helpless by wounds or other injuries, may be conveyed when movement is necessary. The mode of transport should be regulated in such a way as to prevent, as far as possible, any aggravation of the existing weakness or pain. The recumbent position is, of course, by far the best—the easiest and safest—for almost all cases. It is only for wounds and other injuries of the upper part of the body that the sitting posture can sometimes be preferred. In such cases, the "four-hand seat" (or "sedan chair" of school-boys), forms a comfortable conveyance. Two assistants are required; each grasps his own left forearm just below the elbow, and with the disengaged left hand grasps the right forearm of the other also below the elbow. The patient is then raised into the seat so formed and supports himself by placing his arms around the necks of the bearers. Two bearers can also, of course, carry a patient who is prostrated by loss of blood or other weakness, in the horizontal position for a short distance, by standing side to side, and holding the forearms in a horizontal position, while the patient himself partially supports himself by grasping the shoulders of the bearer who is next his head.

Of the modes of conveyance which are prepared for the transport of the sick and wounded, the stretcher and hammock are the simplest. The former, with the addition of a pole on each side, forms a very simple and very efficacious means of transport for moderate distances. Two bearers may be employed; four, if the services of so many are available. A hammock, made from either cord or canvas suspended from a single pole, is often employed, the ends supported on the shoulders of two bearers. When nothing else can be procured, a great-coat, with the sleeves turned inside out, and through which two rifles, poles or pikes are passed, will be found to answer the purposes of an improvised stretcher fairly well. In the use of all such modes of conveyance it is very desirable that the movements of the bearers should be as gentle as possible. The steps should always be short, and the front and rear bearers should always break the step, by starting with opposite feet. This prevents dipping from side to side, which would be, of course, very distressing to the patient.

Animals can, of course, be employed as modes of conveyance for the sick and wounded. Whenever they are so utilised, the preference should be given to the smaller ones—such as mules, ponies, and donkeys. The invalid is then more readily raised into position, and more readily taken down. It is hardly necessary to say that a steady, even gait, combined with a fair amount of strength and power of endurance are to be looked for; and not at all such qualities as high mettle, showy action, or speed. A *litter* can be easily improvised, when the animal has been chosen. The rapidity and efficiency of the Arab method of conveying their wounded from the field of battle has often been commented on, and is well worth mentioning here. Mules are used for the purpose, and are kept ready saddled. Two large sacks, stuffed with straw, grass, etc., are firmly corded—one on either side of the pack-saddle, and the grooves between these and the saddle are filled by stuffing of similar material. On the litter so formed, a cloak is thrown, and the helpless invalid is then placed *across* the animal, lying in the recumbent position on the bed so prepared. This arrangement reduces the jolting of the patient to a minimum. If the emergency is very great, the person so placed can be secured by tying, and can then be conveyed at a gallop, out of the reach of shot, etc. When there is a large party of travellers, supplied with all the luxuries of transport, there are usually no such difficulties met with

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as those I have implied. The presence of a sufficient number of attendants, with animal transport, and properly-prepared *litters* and *cacolets*, will obviate the necessity for the consideration already given.

Wheeled conveyances may, of course, be utilised when there are roads. Some other modes of conveyance may be mentioned, which have been from time to time employed instead of the more primitive stretcher or hammock, viz. the *Himalayan dandy*, the *trag-sitze* of the Germans, the New Zealand *amoo*, the Indian *dooley*, the Chinese *palanquin*, etc., etc. Any of these may be employed when at hand in the conveyance of the sick and wounded. Ox hide and bamboo are nearly always at hand in Africa, and are useful for making improvised stretchers at the shortest notice.

IV.

SURVEYING AND ASTRONOMICAL OBSERVATIONS.

By JOHN COLES, F.R.A.S., *Instructor in Surveying and Practical Astronomy to the Royal Geographical Society.*

PART 1.

INSTRUMENTS USED IN SURVEYING.

Preliminary Remarks.—The intending traveller who proposes to undertake the survey of an unexplored country, should make himself acquainted with the use and adjustments of every instrument he purposes to employ; he should have a knowledge of plane trigonometry, and those computations of practical astronomy which are necessary to enable him to fix his position in latitude and longitude; and although from his note-book he may furnish cartographers with valuable material, yet, without such previous training, it is scarcely possible for him to map the country through which he travels, nor will he be able to take full advantage of these 'Hints,' as the greater part of the matters dealt with will be beyond his comprehension. The attainment of this necessary amount of knowledge is by no means difficult, and a few weeks of study, under proper instruction, ought, in most cases, to enable him, by the aid of the following pages, to do useful geographical work. It is with this end in view that this section of 'Hints to Travellers' has been written in the simplest form, in the hope that it may serve as an introduction to, without at all superseding, the necessary text-books on practical astronomy.

1. Scientific Outfit.*

Sextant for regular work—

A sextant of 6-inch radius, light in weight, by a first-rate maker, divided on platinum, to ten minutes, to read with vernier to ten seconds. It should have a moveable ground-glass screen in front of the reading-off lens, to tone down a glaring light. The handle must be large and convenient; the box capacious enough to hold the instrument with its index clamped to any part of the arc, and the receptacle for the inverting telescope long enough to allow of it being put into the box when set at focus.

Sextant for detached expeditions, and for taking altitudes when the other sextant is in use for lunars—

A sextant of 3-inch radius, graduated to 20′ to read with vernier to 20″, in a leather case, fitted to slip on to a leather belt, to be worn round the waist, when required.

Mercurial Horizon—

One of the common form with folding roof by a good maker, or the form devised by Captain George, R.N., may be preferred. (*See* p. 107.) *Reserve:* an iron bottle of pure mercury.

Watches—

A keyless silver half-chronometer watch, not too heavy, with an open face and a second hand. The hands should be of black steel, long enough to cover the divisions. The divisions should be very clear and distinct. See that the second hand falls everywhere truly upon the divisions. *Reserve:* at least two more good watches; these should be rolled up separately, each in a loosely-wrapped parcel of *dry* clothes, and they will never come to harm; they should be labelled, and rarely opened. The immediate envelope should be

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* It will be understood that the necessity for taking all the articles herein enumerated will depend upon the nature of the journey.

free from fluff or dirt. Covers of chamois leather should be washed before use. Three spare watch-keys; one might be tied to the sextant-case, one wrapped up with each watch. (*See* p. 130 for further particulars.)

Mem.:—Chronometers are designedly omitted from this list, on account of the proved difficulty of transporting them without injury, and the frequent disappointments they have caused, even to very careful travellers.

Compasses—

A prismatic compass, graduated on silver or aluminium, from 0° to 360°.

Two pocket compasses, from 1½ to 2 inches in diameter. The graduations on their cards should run from 0° to 360°, and not twice over from 0° to 180°. A line for True North, temporarily marked on the cards, in the position most appropriate to the magnetic variation in the country about to be visited, may be found convenient. These compasses should be light in weight, have plenty of depth, and be furnished with catches, to relieve the needle from its pivot when not used. The needles should work smoothly and quickly: such as make long, slow oscillations are to be avoided. Cards, half black and half white, are recommended. (*See* p. 93 for further particulars.)

Steel Tape—

A 100-foot steel tape will be found very useful in measuring a base, or when making plans. A fishing-line on reel for roughly measuring a base, with knots at convenient intervals, will, under certain circumstances, be useful.

Lantern—

All lanterns should be made of copper or brass, as they will otherwise affect the compass reading when taking the bearing of a heavenly body at night, and should be constructed for long journeys and hot climates, to be used with oil, and furnished with a large wick. A candle lantern is more convenient where

candles can be carried. See that there is abundant supply of air-holes in the *sides*; these are essential when the lantern is set upon the ground. Also that all the internal fittings can be removed and cleaned, and that they are solidly made, not merely soldered. It should be furnished with a reflector, to throw a clear light forwards and *downwards*. A moveable shade of light green glass will be found to be a great improvement, as it prevents the light from dazzling the eyes, and enables the observer to take the reading on the sextant with greater ease. A good lantern is *most important*. For general purposes, the Italian Alpine Club lantern is one of the best forms. A small ball of spare wick, oil of the best quality obtainable, and wax tapers, for use on detached expeditions, should also be taken.

Thermometers—

Several sling thermometers.

A pair of maximum and minimum thermometers, fitted in one case.

Three short and stout boiling-point thermometers, with apparatus for boiling them. (*See* p. 95 for further particulars.)

Two ordinary thermometers, which should be graduated from 10° or more below the freezing- to above the boiling-point.

Standard thermometers, at a charge of 1*l.* each, graduated at the Kew Observatory, may be obtained thence, on the application of any Fellow of the Royal Society, or Member of the British Association.

Aneroids—

Aneroids of ordinary construction should be of large pocket size ($2\frac{1}{2}$ inches across), capable of working without fracture over the highest mountain pass that is expected. They can be obtained graduated up to 20,000 feet at most instrument makers. At any such height, however, their records are not to be depended on. Aneroids are excellent for most differential observations, but *unreliable for absolute* ones; they should be observed, as much as possible, in conjunction with the boiling-point thermometers. Two

are required, because simultaneous observations are important. Recollect that such observations, taken even at distances of two or three hundred miles apart, are of value, as the areas are usually very large over which the barometer has nearly the same height at the same moment of time Watkin's patent Aneroid differs from the Aneroid of ordinary construction by having its scale drawn on three concentric circles, instead of the usual single circle. This arrangement admits an increased scale of graduation, and consequently of closer and more accurate reading. It is manufactured by J. J. Hicks, 8, Hatton Garden. For Barometers, *see* "Additional Instruments" (p. 89).

Mapping Instruments—

A small case of drawing instruments, containing, among other things, hair-compasses, drawing-pen, and a rectangular protractor, with scales of chords, sines, tangents, &c., engraved on it.

Marquois's scales, for ruling parallel lines at definite intervals.

Protractors: one circular, of metal, and one of celluloid, of 5 or 6 inches in diameter; one of vulcanite, 5 inches, all graduated, like your prismatic compass, from 0° to 360°.

A graduated ruler of 1 foot or more, in metal: 2 dozen artist's pins. Medium size measuring tape, say 12 yards; pocket ditto, 2 yards.

Stationery, &c.—

An artist's board, not less than 8 inches by 13, made of light, well-seasoned mahogany, and what cabinet-makers call "framed," to rule and draw upon.

Plenty of good ordinary paper. Reporters' note-books ruled (not "metallic," for prepared paper wants strength, and the leaves of such books are very liable to become torn out and lost; they are also damaged by wet). They should be all of one size, say 7 inches by 4½, or larger, and numbered. A leather pouch, secured to the waist-belt, having a flap buttoning easily over, to hold the note-book in use.

Two (or more) MS. books of strong ruled paper, foolscap size, each

with a leather binding; the pages should be numbered, and journal observations, agreements, and everything else of value, written in them.

Some sheets of blotting-paper cut up and put here and there in the books.

Transparent cloth for tracing.

Plenty of brass pens and holders; also fine drawing-pens (steel crow-quills—Brandauer's Oriental pens are very good) and holder. FH pencils; HB ditto.

Penknives. India-rubber cut up in bits.

Ink-powders of a kind that do not require vinegar. Red ink.

Paints for maps, viz., Indian ink, sepia, lake, cobalt, gamboge, oxgall, in a small tin case.

A dozen sable paint-brushes.

Materials for "squeezes," if travelling where inscriptions may have to be copied (*see* page 455).

Paint and brush for marking on trees or rocks record of positions.

Books, Maps, &c.—

Raper's Practice of Navigation; or, in default of this, either Inman's Navigation and Tables (bound together), or Norie's Navigation.

Chambers' Mathematical Tables are very comprehensive and useful.

Shadwell's Cards of Formulæ (Potter, 31, Poultry, London); Bethune's Tables for Travellers (Blackwood and Sons).

With the help of either of these two latter publications, the traveller, who has a fair knowledge of mathematics, will thoroughly understand what he is about, and may, on emergency, dispense with some of the usual cumbrous tables, confining himself to ordinary tables of logarithms. But we have recommended that all travellers should be furnished with a complete set of tables, because they afford at a single reference, what otherwise requires additional trouble to obtain.

'Nautical Almanac' for current and future years, strongly stitched in cloth.

Some small Almanacs, such as 'Whitaker's,' contain tables of the position of sun and planets, and of stars to be occulted. One of

these is useful to afford what is necessary to take on a detached expedition, the required pages being cut out of it.

More extended barometric tables than are given in this volume may be procured at the instrument maker's, or cut out from Guyot's elaborate Meteorological tables, published by the Smithsonian Institution, New York.

Blank maps, ruled for the latitudes and longitudes of the proposed route.

The best maps obtainable of the country you propose to visit.

Admiralty Manual of Scientific Enquiry.

Mem.:—Chauvenet's Astronomy (New York, 2 vols.) is one of the most complete and thorough of the mathematical works on astronomical observations; it is, however, a book for previous study, rather than for reference in the field.

Additional Instruments, not necessary, but convenient.

Theodolites—(*See* p. 108.)

Barometer—(*See* p. 97.)

Barometers of Fortin's pattern were successfully carried to great heights by Mr. Whymper, in South America; but the risk of breakage, at all times very great, is proportionally greater on longer journeys. The Boylean-Mariotti barometer is an extremely portable instrument, and is well calculated for use at great elevations (see p. 97). Captain George's barometers, which are carried with empty tubes and filled when required, are much more portable than the ordinary form of mercurial barometers; but the filling them is a work of time and delicacy, which may be difficult, or even impossible, on a mountain top with an icy wind blowing.

Care should be taken to see that all barometers read low enough to be used at great elevations.

Telescope for observation of eclipses of Jupiter's satellites, &c. (*see* pp. 214 and 235). One with a two-inch object glass, clear aperture, by a good maker. It should be mounted on a split tripod, and furnished

with a Kelner eye-piece, of not less magnifying-power than 40, and should be fitted with an arrangement by which it can, when removed from the stand, be screwed firmly to a tree or other support. The telescope should be tried on Jupiter, and found to give a satisfactory view of the satellites, before it is taken.

Plane table.—Two plane tables, and spare horse-hair for sight vanes. They should be in strong canvas bags with leather-covered corners, and furnished with straps, so that they can be carried like a knapsack. For information as to use and the best form of construction, see pp. 124–173.

Pedometer.—Apt to get out of order. If employed, at least three persons should each carry one.

Clinometer.

Pocket level (Abney's), with a mirror to show where the bubble is, when it is held to the eye. It also serves as a clinometer for the measurement of slopes.

Rain gauge.

Examination of Instruments.

Let every instrument be tested, and its errors determined and tabulated at the Kew Observatory.* This is done for moderate fees. The following are some of the present charges:—Watches, A class, £1 1*s.*, B class, 10*s.* 6*d.*; ordinary thermometers, 1*s.*; boiling-point thermometers, 2*s.* 6*d.*; marine and portable barometers, 10*s.* 6*d.*; prismatic compasses, 2*s.* 6*d.*; theodolites, 5*s.*; superior sextants, 5*s.* Unifilars, dip circles, and other magnetic instruments are also verified. The carriage of the instruments to and from the Observatory must be paid. Address—" Superintendent

* This should be attended to by the traveller, especially in the case of thermometers which have been previously examined at Kew Observatory, as it has been found that their errors change considerably; for instance, a boiling-point thermometer which was tested in 1884 was found, in five years, to have increased its error at some readings by no less than ·2 of a degree, and in no part of the scale by less than ·1 of a degree.

of the Kew Observatory, Richmond, Surrey." The establishment lies ten minutes' walk from the Richmond railway station. Any persons ordering instruments from opticians may direct them to be previously forwarded to Kew for verification, either to the above address, or through the receiving establishment at the Meteorological Office, 63, Victoria Street, Westminster, S.W.

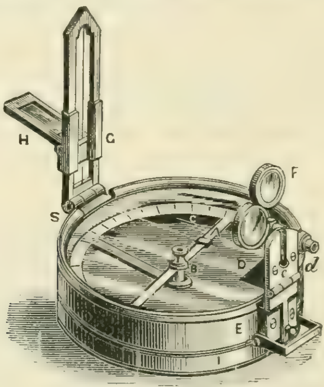
Packing.

It is difficult to give general rules, because the modes of transport vary materially in different countries. Inquiry should be made by the intending traveller at the Royal Geographical Society's rooms as to the kind of packing best suited for his special purposes and field of exploration. The corners of all the instrument cases should be brass-bound; the fittings should be screwed, and not glued; and the boxes should be large enough to admit of the instruments being taken out and replaced with perfect ease. Instrument makers are apt to attend over-much to compactness, making as much as possible go into a small solid box, which can easily be put on a shelf; but this is not what a traveller wants, bulk being rarely so great a difficulty to him as weight. Above all, it is most important that he should be able to get at his instruments easily, even in the dark. He should notice particularly the manner in which the instrument is placed in its box, before taking it out, *and in the case of a theodolite, observe the positions of the verniers, and the object end of the telescope*; attention to this will prevent much loss of time and possible injury to the instrument. Moreover, a large, light box suffers much less from an accidental concussion than a small and heavy one. Thermometers travel best when slipped into india-rubber tubes in a brass casing. A coil of such tubing will serve as a floor, to protect a case of delicate instruments from the effects of a jar. Horse-hair is of use to replace old packing, but it has first to be prepared by steeping in boiling water, twisting into a rope, and, after it is firmly set, chopping it into pieces. The hairs retain their curvature and act as springs. Instruments travel excellently when packed in *loose, tumbled* cloths.

2. Instruments, and their Adjustments.

Compasses.

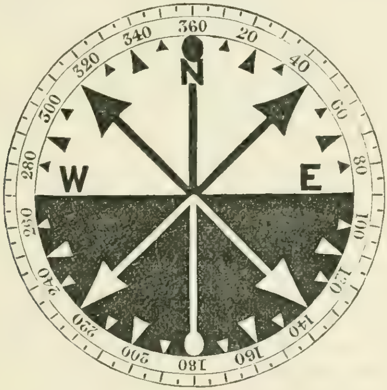
This instrument consists of a magnetic needle, A, balanced on a pivot, B, carrying an aluminium ring, C, divided into 360°; it is graduated from the *south* pole of the needle,—by west, north, and east to south again, from 0° to 360°; the 0° is not shown on the ring, since it coincides with 360°. A prism, D, is fixed on one side of the box, E, mounted on a hinge-joint, *d*; it can be turned down when not in use, and is attached to a plate, *e*, which slides up and down to suit the vision of the observer. In the plate there is a slit through which the observer looks; it has also an



Prismatic Compass.

arm with two dark glasses F, to protect the eye when taking a bearing of the sun. On the opposite side of the box is a sight-vane G, having a fine thread down its centre, and a mirror H, which slides on and off as required; it can be used with its face up or down, so as to reflect images of objects which cannot be directly observed. The sight-vane is also fitted with a hinge-joint, and when shut down presses on a lever, which lifts the needle off the pivot. In front of the sight-vane there is a small stud S, by pressing which with the finger the ring is brought to rest;

it also serves to check the vibration of the needle. The box E has a cover I, which fits either the top or bottom, in which latter position it is shown in the drawing, and with it the instrument can be held when taking an observation. The prismatic compass is frequently fitted to screw on to a light tripod, with a ball and socket adjustment, and can then be used with great accuracy either for taking bearings, or as an angular measuring instrument.



Pocket Compass.

A prismatic compass is not suited for taking bearings, except through the prism, on account of the reversal of the figures, and their arrangement from the south point; it will therefore be convenient, for taking rough bearings, for the traveller to provide himself with a pocket compass having a card of the size and pattern shown above; it should be made of aluminium, which is both light and strong. The compass box should be fitted with a lever to throw the magnetic needle off its centre when the compass is not in use, and the glass should be thick, flat crystal. For night work a luminous pocket compass will be found useful.

Observations with the Prismatic Compass:—To take an observation with the prismatic compass, first adjust the prism by sliding it up and

down until the divisions on the circle are seen distinctly; if a tripod stand is used, screw the compass to the ball-and-socket joint, and move the instrument until it is perfectly horizontal (the same precaution must be taken if it is held in the hand); raise the sight-vane, until it is perpendicular; look through the slit in the prism-plate, and bring the thread of the sight-vane in a line with the object; wait until the magnetic needle comes to rest, and read the bearing through the eye-hole in the prism-plate. A bearing thus taken shows the angle which a straight line drawn from the observer, to the object, makes with the magnetic meridian (called the magnetic bearing).

To get the true bearing the magnetic variation must be applied as follows:—If the variation is east add it to the bearing, if west subtract it, and the result in either case will be the true bearing. Thus: the magnetic bearing of an object was 160° and the variation 20° east, then $160° + 20° = 180°$, the true bearing: the bearing of an object was 160° and the variation 20° west, then $160° - 20° = 140°$, the true bearing; but since the magnetic needle will be affected equally by variation within certain limits of time and space, the difference of the bearing of any two objects, taken from the same station, will be the *angle* subtended by them, as the *difference* in their azimuths will not be affected by the variation.

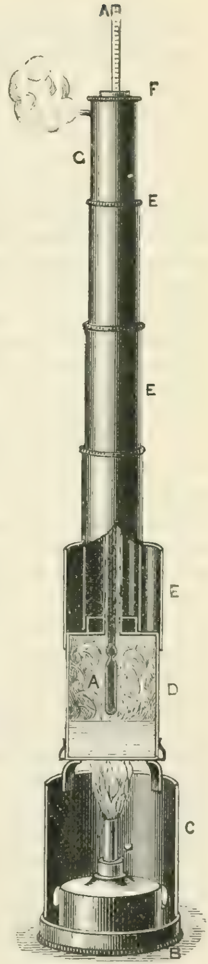
Where possible, the bearings should be taken at both ends of a base, or line of bearing, the mean of which will be the correct bearing. When the sun's azimuth or amplitude has to be taken, one of the dark glasses should be placed before the slit in the prism-plate, and the mirror should be moved on the sight-vane until the reflected image of the sun is seen in the mirror through the slit in the prism-plate; the bearing is then taken in the manner before described. Great care must be observed when using this instrument to avoid all magnetic rocks, as they may so affect it as to render bearings taken in their vicinity useless.

Hypsometrical Apparatus.

The boiling-point apparatus consists of a thermometer, A, generally graduated from 180° to 215°*; a spirit lamp, B, which fits into the bottom of

* When it is intended to be used at very great elevations, the thermometers will have to be specially constructed with extended scales.

a brass tube, C, that supports the boiler, D; and a telescopic tube, E, which fits tightly on to the top of the boiler. The thermometer is passed down the tube, E, from the top until within a short distance from the water, *which it should never touch*, and is supported in that position by an india-rubber washer, F. The steam passes from the boiler up the tube, E, and escapes by the hole, G. To pack this instrument for travelling, withdraw the thermometer, and put it into a brass tube, lined with india-rubber, having a pad of cotton-wool at each end; take off the tube, E, shut it up, and put the small end into the boiler, D, which it fits, then withdraw the spirit lamp, B, screw the cover over the wick and replace it in C. The whole of this apparatus fits into a circular tin case, 6 inches long, and 2 inches in diameter.



To use the boiling-point thermometer:—Take the apparatus to pieces, pour some water into the boiler, D, about one quarter full is quite sufficient; then put the instrument together as shown in the drawing, taking care that the thermometer is just clear of the water, and light the spirit lamp; as soon as the water boils, the steam ascending through the tube, E, will cause the mercury to rise; wait until the mercury becomes stationary, and then read the thermometer; at the same time, take the temperature of the air in the shade with an ordinary thermometer.

If the traveller is visiting a region where the elevations are very great, he should, when purchasing this apparatus, see that the thermometers are capable of registering a greater height than those which are usually supplied, and that the lamp is large enough to hold a good supply

of spirit, as it is a common fault to make it too small. A screen, which may be made of tin to fold up, is most useful to place on the windward side, and at a very low temperature is almost indispensable, as the heat is otherwise carried off too rapidly for the water to boil properly.

The Aneroid.

The general appearance of the aneroid is so well known that it requires no special description; it is an excellent instrument for laying down contour lines; but for absolute heights it should be checked by the boiling-point thermometer, because its index error is apt to change; when thus checked it is a valuable instrument for measuring heights up to 8000 feet, but at greater elevations it is generally unreliable. It should be sent to Kew Observatory to be tested, and have its errors determined before and after it has been used by a traveller for the purpose of measuring heights, and during the journey every opportunity should be taken of comparing them with mercurial barometers.

In the majority of cases, aneroids, even when they have been in the first instance correctly graduated, do not read accurately against the mercurial barometer at diminished pressures, and will be found almost always to possess more or less considerable plus or minus errors. These errors are tolerably constant in good instruments, though they are frequently considerably augmented when low pressures have been experienced for a length of time.

Aneroids should be treated with almost as much care as chronometers, and should not be allowed to dangle about the person, or to be shaken up in pockets. If the watch size is employed, they can be conveniently carried in extra watch pockets.*

Measurement of Heights with the Aneroid :—To measure the difference in height between two stations, two instruments should be used, and the readings taken simultaneously at both stations; but it frequently happens that this is impossible, in which case the observations should be taken in the following manner:—Take the reading of the aneroid and the temperature of the air, *in the shade*, at the lower station; repeat

* On this subject the traveller will do well to read Mr. E. Whymper's book, 'How to use the Aneroid Barometer.' J. Murray, London.

this at the upper station, and again at the lower station on returning to it, but before taking this last reading a short time should be allowed to let the aneroid take up its proper working, as a descent will always in a greater or less degree affect it.

In observing with the aneroid, the instrument should always be in the same position, as, for instance, with its face vertical; merely altering the position affects most aneroids with a very sensible difference of reading.

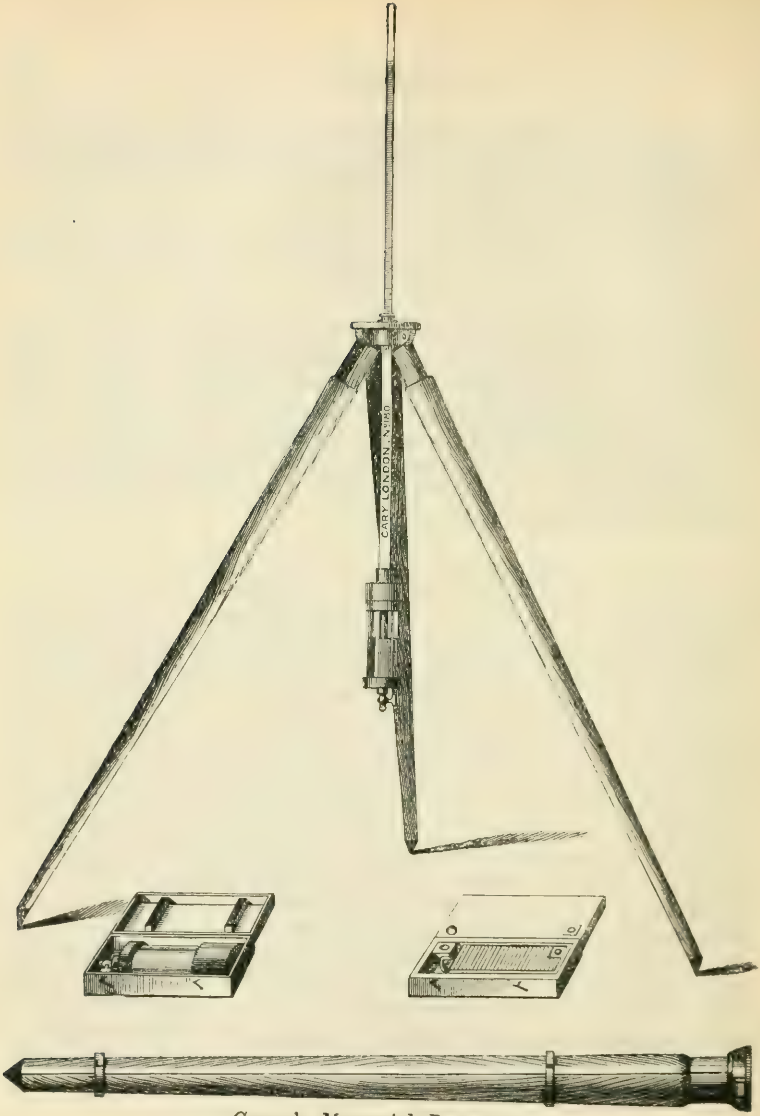
On leaving a station to which it is not intended to return, the reading of the aneroid should be taken, and the temperature in the *shade;* during the day's journey the difference between any reading and that taken at starting will approximately give the difference of height unless there has been some atmospheric change. This is only a very rough way of ascertaining whether a party, passing through a hilly country, has ascended or descended; for the accurate method of computing the difference of height of two stations, see examples (p. 318).

The Boylean-Mariotti Barometer.

This instrument consists of a short centre glass tube, a lower open air tube with diaphragm joined to it with a vulcanite covering for insulation and a brass tube which covers the glass tube, and on which the graduations and figures are engraved. Attached to this is a cistern filled with mercury, which has a tap and a coarse screw adjustment. The total length of this instrument is from twelve to fifteen inches, but for convenience of carriage the cistern may be detached at pleasure, and carried separately.

To use the instrument:—At a convenient height for the eye, suspend the barometer freely by a string tied to the brass ring at the top of the instrument. Then turn on the tap of the cistern containing the mercury, and, keeping the barometer steady and in a perpendicular position with the left hand, with the right commence to turn the screw at the bottom of the barometer from left to right, at the same time looking through the small narrow slot just above the larger opening in the lower part of the barometer. After turning the screw for some time, the mercury will be seen to rise in the tube of the barometer, and, though much slower, to be filling the lower part of the instrument, seen through the larger opening.

When the mercury has risen for a considerable height, watch carefully



George's Mercurial Barometer.

through the smaller and upper slot, and continue to turn the screw slowly until a bubble is seen in this slot, taking care to keep the barometer steady and in a perpendicular position. Let the top of this bubble just reach the upper part of the slot, and then bring the *lower* edge of the upper or lower vernier (whichever is most convenient) on a line with the top of the mercury in the barometer tube, and take the reading in the ordinary manner. The reading should be taken *directly the barometer is set*, as it is only true at that instant, and the barometer should not be handled more than is absolutely necessary, as the heat of the hand alters the temperature of the instrument, and consequently the reading.

Captain George's Mercurial Barometer.

To Fill:—Spiral Cord Method, Take the tube out of the tripod stand, unscrew the short part of brass tube and take out the tube; insert it carefully into the cistern with a screw-like motion through the rubber plug until the end of the tube is opposite the mark in the middle of the cistern. Then screw on the smaller half of the brass tube and pass it down through the top of the stand (cistern uppermost) until it rests on it. Take off the bottom of the cistern, and thrust the feather end of the spiral cord down to the bottom of the tube. Now take the filterer and pour the mercury down the orifice of the tube until the cistern and tube are filled. Give the spiral cord circular motion from right to left until it works itself out of the tube, when fill in mercury up to the top of cistern.

Screw on the lower stopper tight, take the barometer out of the stand, and invert it: try if it gives a sharp metallic click-like sound: if it does there is a perfect vacuum; if it does not, there will be air in the tube, and the whole process must be repeated. Pass it upwards through the centre of the tripod stand, guiding the projecting arms through the notches, and giving it a quarter turn, land it in its place, where it will swing perpendicular.

Let it rest a few minutes, read off the upper scale *first* and then the lower; their *difference* is the true reading, if the zero is immersed in the mercury; but their *sum* if the zero is above the mercury in the cistern.

To Empty the Barometer.—Screw down the flange, and thus secure the mercury in the cistern.

Take the barometer out of the stand. Reverse it carefully, and unscrew the lower cap, tapping it gently to shake off the globules into the cistern.

Empty out the mercury into the wooden box, holding the fore-finger across the lower part of the orifice of the cistern. This prevents its rushing out too quickly, and avoids spilling the mercury. Place the empty barometer in its stand.

Pour the mercury from the wooden box into the iron bottle. Secure it by the screw plug.

Clean the tube and cistern, inside and out, and it will be ready for re-filling again, or being stowed away in its stand and case.

The Sextant.

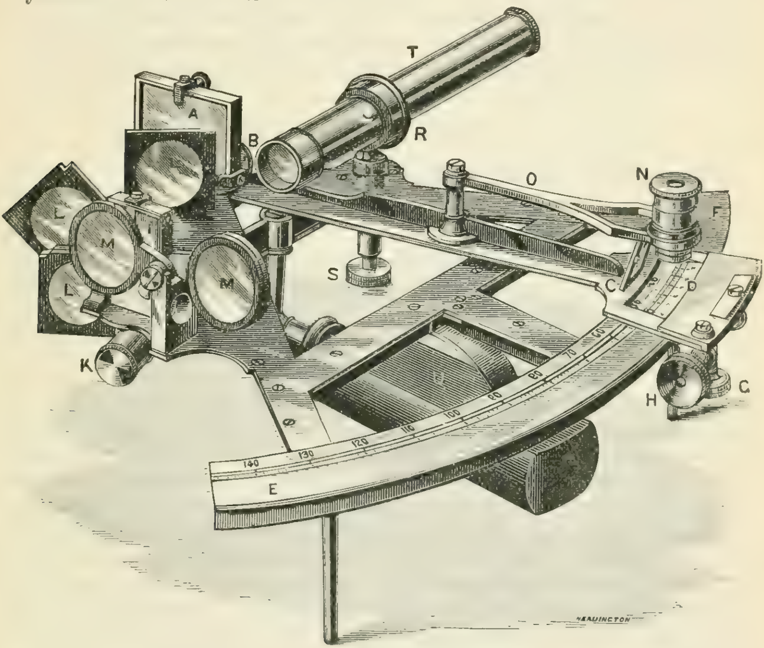
The principle on which the sextant is constructed is this:—that the angle between the first and last directions of a ray which has suffered two reflections in one plane, is equal to twice the inclination of the reflecting surfaces to each other. The arc on which the angle is measured must therefore be divided into double the number of degrees which properly belong to an arc of the same extent. With this instrument we can measure the angle between two objects, in whatever direction they may be placed, provided the angle is within its limits.

With the aid of the following figure, the different parts of the sextant, with their names, may be distinguished.

A is a plane mirror called the *index glass*; it is set in a frame, and is fixed on a centre perpendicular to the plane of the instrument; it moves with the *index bar* B C, the end of which C slides over the *arc* E F, which is graduated (on an inlaid plate of platinum or silver) from 0° to about 140°; each of these degrees, according to the radius of the instrument, is divided into 10′ or 20′, and these are subdivided by the *vernier* D into 10″ or 20″; these divisions on the arc are continued a short distance on the other side of zero (0°) towards F, forming what is termed the arc of excess. The index is secured to the arc by a *clamp screw* G, which must be released when the index has to be moved over a large portion of the arc. In order to obtain the slow motion necessary for the accurate measurement of an angle, a *tangent screw*, H, is fixed to the index, but does not act until the index is fastened by the clamp screw.

I, is a fixed plane glass, the lower half of which, next to the frame

of the instrument, is silvered, and the upper half left clear. It is called the *horizon glass,* and must be perpendicular to the plane of the instrument, in such a position that its plane shall be parallel to the plane of the index glass when the index points to zero (0°) on the arc; it is adjusted by means of the screw K*.



L and M are coloured glasses of different depths of shade, any one or more of which can be turned down in front of either the index or horizon glass to moderate the intensity of the light before reaching the eye,

* The form and position of this screw differs very much in different sextants; in many, the adjustment is made by two small screws bearing on the back of the glass.

when a bright object, such as the sun, is observed. N is a *microscope* which is carried on a moveable arm O, and can be adjusted to read the divisions on the graduated arc and vernier. The *telescope* T is carried by a double ring, R, so constructed that it furnishes means of adjusting the line of collimation: this ring is attached to a stem S, which can be raised or lowered until objects seen by reflection, and directly, appear of the same brightness. U is the handle which is sometimes fitted with a brass centre, having a hole in it, to admit of its being fastened to a stand.

Adjustments of the Sextant.

The principal are the following:—

1. To make the index glass perpendicular to the plane of the instrument.
2. To make the horizon glass perpendicular to the plane of the instrument, and parallel to the index glass when the index points to zero (0°) on the arc.
3. To make the axis of the telescope parallel to the plane of the instrument, in which the index moves.

1*st Adjustment*.—This adjustment rests with the maker; and being once made cannot be deranged, except by a fall or blow, against which every precaution must be taken. The instrument should, however, be occasionally verified by the observer in the following manner:—Set the index at 60°; and, holding the sextant in the left hand, with the right move the index gently backwards and forwards, looking, as you do so, obliquely into the index glass; then, if the image of the arc in the mirror appears in perfect continuation of the arc itself, the adjustment is perfect; when this is not the case, the index glass is out of adjustment. If the derangement is great, the sextant is for the time being useless; if small, it may possibly be remedied by means of certain screws sometimes fitted at the back of the glass; but it is better to leave it alone, as an inexperienced observer would most probably only make it worse. A man who has a thorough knowledge of his instrument can take off the frame, and, by hammering and tinkering, get it put square and straight; in replacing it, wedging it up, if necessary for perfect adjustment, with small folds of paper. A bad derangement may be put

to rights in this way; but it is, very evidently, a thing not to be rashly attempted.

2nd Adjustment.—Having screwed in the telescope, look through it and the horizon glass at the sun, or still better, a star, and move the index backwards and forwards, on each side of zero (0°), when the reflected image of the object ought to pass exactly over the object itself. If it does not do this, but passes either to the right or left of it, the horizon glass is out of adjustment, and its adjusting screw must be gently turned until the reflected image does pass directly over the object itself.

3rd Adjustment.—Screw the telescope firmly into the collar, turn the eye-piece until two of the wires in the focus of the telescope are parallel to the plane of the instrument. Select two stars, not less distant from each other than 90°, bring them into exact contact at the wire nearest to the plane of the instrument; fix the index, and move the instrument so as to throw the images upon the upper wire; if the contact remains perfect the adjustment is perfect: if not, it must be rectified by the two opposing screws in the double collar, taking care to slacken one before tightening the other: the one to slacken is that on the side towards which the contact opens.

Index Error.—When the index is set at zero (0°) on the arc, the horizon and index glasses should be parallel, and the two images of a distant object, as a star, should exactly coincide; when this is not the case, it may be remedied by turning a screw in the mounting of the horizon glass. If this adjustment is not made, there will be an error in the place of the *beginning* of the graduation; this is called the Index Error; its amount is easily determined, and, as it affects all angles alike, it is usual to admit the existence of this source of error, and apply correction for it, in preference to making the adjustment.

To find the Index Error by a Star.—Set the index at zero (0°), screw in the telescope, and, with the tangent screw, make the two images of a star, as seen through the telescope, coincide; then the reading on the arc will be the index error. Subtractive when the reading is to the left of zero, additive when to the right.

By the Sun.—Clamp the index at about 30′ to the left of zero, and looking through the telescope at the sun, the images will be seen nearly in contact; make this contact perfect with the tangent screw, take the reading, and call this "on the arc"; next, set the index, at about 30′ to

the right of zero, and make the contact of the two images perfect as before, take the reading, and call it "off the arc": half the difference of these two readings is the Index Error.

Examples.

(1)

	′	″
On the arc	33	10
Off the arc	29	30
2)	3	40
Index corr. *subtract* =	1	50

(2)

	′	″
On the arc	29	30
Off the arc	33	10
2)	3	40
Index corr. *add* =	1	50

As a check on this observation, for inexperienced observers, it may be noted that one-fourth of the sum of the readings on and off the arc ought to be the sun's semi-diameter, as given in the 'Nautical Almanac.'

Centering Error.—In addition to the foregoing, every sextant is liable to errors caused by:—

1. The centre of the pivot of the index-bar carrying the vernier not being identical with the centre of the arc.
2. Imperfect graduation of the arc.
3. Flexure of the whole instrument caused by irregular expansion under the heat of the sun.
4. Shocks or blows which may cause bending of parts of the frame, or of the index bar, and thus cause eccentricity between the vernier and arc.

These errors are generally included in the term "centering error."

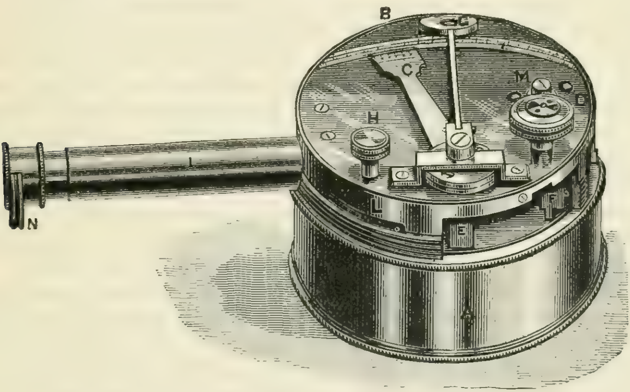
The original error included in [1] and [2] can be determined at Kew, where apparatus for the purpose is established. Those under [3] and [4] are manifestly variable.

In a good sextant the original error should be small, amounting only to a few seconds, but instruments are made which have much larger errors, and as these are enormously multiplied in their effect in some observations, as *e.g.* lunars, a traveller should always have this error determined before leaving England.

The Box or Pocket Sextant.

The box sextant is constructed on the same principle as the larger sextant; it is enclosed in a brass box, varying in size from 3 to 4 inches in diameter, and from an inch and a half to two inches deep.

This instrument is very portable, light, and easily adjusted. It is more correct than the compass for measuring horizontal angles, as an angle can be read to within 1′ by means of the vernier on the graduated arc. It can also be used on horseback, and in all sorts of weather, and, when not required for use, can either be carried in the pocket, or slung in a leather case over the shoulder.



The instrument, as shown in the drawing, is ready for use: the *cover*, A, is screwed on to the lower part of the instrument, and serves as a handle when taking an angle; B is a graduated *arc*, divided into degrees and half degrees; C is the *index bar*, having a vernier at the end, divided to read the angle to 1′; D is a *milled screw* by which the index bar is moved; attached to the end of the index bar, on the inside of the box, is the *index glass*, E; the *horizon glass*, F, is also inside the box, one half of which is silvered; G is a small *magnifying glass* attached to the top, to enable the observer to read the angle more clearly; there are

dark glasses, to be used when observing the sun, not shown in the drawing. H is the *adjusting screw*, which is screwed into the top for safety; it is made with a square, like a watch-key, and when required for use has to be removed from the position shown in the drawing; I is the *telescope*, which should be fitted at the eye-end with a *revolving disc* N, which is provided with shades of different intensity, to be used with the artificial horizon; in taking angles the instrument can be used without the telescope, by drawing the *slide*, L, over the hole from which the telescope has been removed.

Adjustments:—Having set the index at zero (0°) on the arc, select some object that is sharp and perpendicular, as far distant as possible, to be seen clearly; then, holding the instrument in a horizontal position, look at this object through the eye-hole, and, if the reflected image coincides with the object seen directly, the adjustment is so far correct. Then hold the instrument the contrary way, or vertical, look at some object that is level, and if the reflected and real objects are seen in a straight line this adjustment is also correct; but when this is not the case the adjustment must be made by taking out the *key*, H, placing it in one of the keyholes, M, either on the top or side of the instrument, and turning it gently until the reflected image of the object coincides with the object seen directly. If the reflected image requires moving up or down, the key must be inserted on the top of the instrument, but when it has to be moved to the right or left the key must be inserted at the side.

These adjustments can be made, when no available objects, such as those mentioned, are in sight, by the sun, using a suitable shade. Set the index to zero, and move it until the reflected and direct images coincide; if the index then points to zero (0°) the instrument is in adjustment, if not, make the coincidence with the key as above described. A bright star may be used in preference to the sun, in which case no shade will be required.

The adjustment by a terrestrial object is here given to meet the case of an instrument having to be adjusted in the day-time when the sun is not visible. Care should be taken when purchasing a box sextant to see that the maker has made the box wide enough to admit a finger to wipe the glasses, as dull reflectors much increase the difficulty of observation.

The Artificial Horizon.

The artificial horizon is a reflector, the surface of which is perfectly horizontal; it is used in combination with the sextant for observing altitudes. Though the principle of all is the same, there are several forms of this instrument, the most common, as well as the best, being a small shallow trough, containing pure, clean quicksilver,* which reflects the image of a celestial body. This is protected from the disturbing effects of the air by a roof, the two sloping sides of which are made of glass plates accurately ground to true planes: these must be carefully examined to see that they are of uniform thickness and density. Should the traveller have the misfortune to break one of his glasses, and replace it by one not tested, he must be careful to reverse the roof between two observations, or once in a set. Captain George's horizon, in which a glass plate floats on the surface of the mercury, is in some respects more convenient; but it is more liable to errors arising from any disturbance communicated to the mercury by wind.

Another form of artificial horizon is the black plate. It generally consists of a plane of black plate-glass set in a metal frame, and levelled by a bubble. This form answers fairly well in the day-time, when the sun is the object observed, but at night there is so much loss of light with the black plate that it becomes extremely difficult to use in star observations. In order to overcome this difficulty, artificial horizons of this class have been constructed with a brass frame containing a black plate on one side, for day observations, and a silvered mirror on the other, for night. To the frame are attached fixed levels, by which it can be brought to a true horizontal position. This is a very portable instrument, but its use can only be recommended in the absence of

* If the quicksilver is not pure it gives an imperfect reflection, and its level is apt to be untrue. The quicksilver of commerce is generally mixed with lead, bismuth and zinc, which have to be dissolved out of it by nitric acid; it may, however, in case of emergency, be rendered serviceable by shaking it for some considerable time in a bottle with a little powdered sugar, or even sand, and afterwards straining it through a piece of fine linen or chamois leather, but it is a troublesome and not very satisfactory process.

a mercurial horizon, and when the glass used in its composition has been ground into a true plane, and tested at Kew Observatory in the same manner as a sextant index-glass. Every care must be taken to level this instrument accurately, or all observations taken by means of it will be of no value. Any form of artificial horizon that is used should be kept clean and free from dust.

Should the artificial horizon be broken or lost, a substitute may be formed by treacle or other viscous liquid, or even, in calm weather, by water, in a tray or basin.

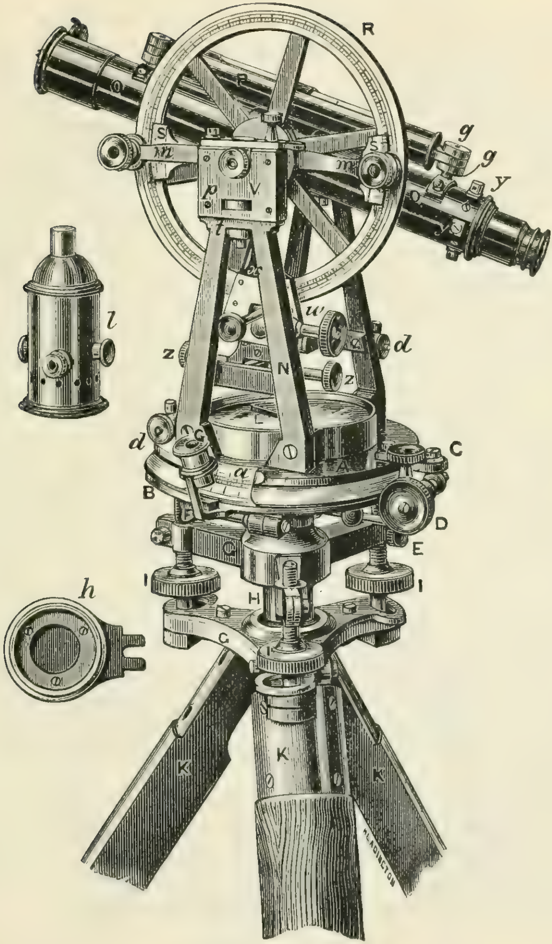
Sextant-Stand.

Though sextant-stands vary considerably in the manner in which they are constructed, the object in all cases is the same, viz.:—to provide a means by which the sextant can be fixed in any position convenient to the observer, and also to give that steadiness, so important in sextant observations, which is often wanting in the traveller's hand after a hard day's journey, or an attack of fever. Cary, 181, Strand, has succeeded in making a very convenient form of this instrument, and one that is in many respects superior to the old form. The only adjustments are to place the stand as level as possible, and in such a position that the plane of the sextant shall be in the plane of observation.

Transit Theodolite.

The following are the names of the various parts of this instrument to which reference is made in the remarks on its adjustments.

A is the *Vernier-plate*; it is furnished with two *verniers*, *a*, 180° apart, graduated to read with the vernier, to 10″. B is the *Lower-plate*; it is graduated into 360°, each degree being again subdivided into 10′, and can, with the vernier, be read to 10″. These two plates combined are called the *Horizontal limb*, and revolve independently of one another, but when required can be made to move together by tightening the *Clamp-screw* C; the slow motion is obtained by the *Tangent-screw* D; the lower plate has also a *Clamp* E, and a *Tangent-screw* F. G G is the *Tribrach System*. H is the *Horizontal axis*. There are three *Levelling screws*, I, I, I. K is the *Tripod*, on which the instrument is firmly screwed; underneath, in the



Transit Theodolite.

centre, there is a hook (not shown in the drawing) from which to suspend a plummet in order to indicate the exact position where the station peg is to be driven into the ground. The vernier-plate carries a *compass* L in its centre between the supports of the *Telescope* O; it is graduated into 360°, and fitted with a screw M to lift the magnetic needle off its centre when not in use. The two *Frames* N N carry the *bearings* V for the telescope, with its *level* P, and the graduated circles R, called the *Vertical limb*, with its two *verniers* S S, and *Microscopes m m*. The vertical limb is graduated from 0° to 90° through one quadrant, then again from 90° to 0° in the next quadrant, and so on round the circle; the degrees are subdivided into 10′, and, with the verniers, read to 10″. The horizontal axis of the telescope is formed of two cones, the larger ends of which are attached to the telescope tube, while the small ends, called the *Pivots*, *p*, are ground into two perfectly equal cylinders; the pivot which does not carry the vertical limb is pierced, and allows the light of a lamp to fall upon a small reflector (not shown in the drawing) which is screwed into the centre, on the axis of the telescope, and inclined to it at an angle of 45°, by which means the light is thrown directly down the telescope, and illuminates the fine threads, or web, attached to a *Diaphragm* inside the telescope, which is kept in its place and adjusted by the screws *y y*, of which there are four. The *Index-bar*, *x*, is fixed in its place by the *Clip-screws*, *z z*. The vertical-limb is furnished with a *Clamp* and a *Tangent-screw*, *w*; *d d* are *Levels* at right angles to one another; *l* and *h* are the small *lantern* and its *holder*, which fits into a slot in the frame on the side opposite to the vertical limb; *g g* are capstan-headed screws for adjusting the telescope level. The telescope is brought to focus by a milled screw (not shown in drawing) near the object-glass; a diagonal eye-piece is also supplied with the instrument, and is extremely useful in astronomical observations; *t* is a capstan-headed screw used in adjusting the axis of the telescope.

A very useful addition to the transit theodolite is to provide it with a pair of micrometers in the eye-piece, by means of which the distance between the observer and staff of known length can be measured in the manner shown (page 122), in addition to which they increase the efficiency of the instrument for astronomical observation.

Adjustments of the Theodolite.

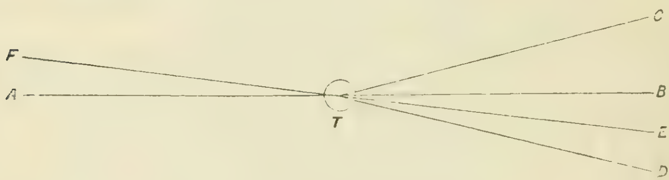
Parallax.—This adjustment is made by moving the sliding tube of the eye-piece until the threads of diaphragm are seen sharply defined against the sky, and then by pointing the telescope O at some object, and bringing it to the proper focus by the milled-head screw near the object-glass. To test the accuracy of this adjustment direct the telescope on some well-defined object, about as far distant as the points to be fixed. Intersect this object accurately by using the tangent screws, with the centre of the threads in the diaphragm. Now move the head laterally as far as the field of view will admit, at the same time watching the intersection of the object with the threads. If the object remains stationary on the threads, parallax has been eliminated; but if it does not, the parallax must be removed by turning the focussing-screw until the object remains stationary in whatever position the head of the observer may be.

Adjustment for Collimation.—Set the instrument as nearly level as can be done with the eye, then clamp the lower plate B, and, having unclamped the vernier-plate A, direct the telescope on some well-defined object, and bring it into coincidence with the point of intersection of the threads of the diaphragm; take the reading on the horizontal limb A B, suppose it to be 20°, then move the vernier-plate, A, half-round, turn the telescope over, and again intersect the object, taking the reading on the horizontal limb, suppose 200° 2′ 30″, take the difference between this and the first reading + 180° (which in the present case would be 200°), and the difference would be 2′ 30″; halve this difference, and subtract it from the second reading, when it is greater than the first reading + 180°, and add it when it is less; this is the mean reading (= 200° 1′ 15″); set and clamp the instrument to this mean reading, and intersect the object by means of the capstan-headed screws *y y*, which move the diaphragm, taking care to loosen one before moving the other. Repeat this operation until the readings taken with the instrument in these two different positions, face right and face left, differ from one another by 180°.

To make the vertical and horizontal wires respectively vertical and horizontal.—As these wires are fixed in the diaphragm by the maker so as to cut each other at right angles, it follows that to adjust one wire is to adjust both, and this may be done by either of the following methods,

the latter being capable of the greater accuracy:—1st Method.—Level the instrument with care, and intersect any small, well-defined point with the vertical wire, and see if it continues bisected along the wire when the telescope is moved in a vertical plane. If this is not the case the capstan-headed screws *y y* must be slackened sufficiently to allow the diaphragm to be revolved until this condition is secured, when they must again be tightened. It will now be found that the horizontal wire, if properly placed by the maker, will continue to bisect an object on which it has been placed when the instrument is turned in azimuth.

2nd Method.—Set up the theodolite as at T (*see* figure below) and level it carefully. Set up a stake, with a mark on it, at such a distance that the mark is distinctly visible, as at A. Turn the telescope on it and accurately cover the mark with the intersections of the cross wires in the diaphragm,



and clamp it in azimuth. Next turn the telescope over and set up another stake, with a mark on it, at the same distance from the instrument as A, and move the stake until the mark on it is accurately covered by the intersection of the wires. If the collimation is in adjustment the stake will be at B, but if not it will be in some other position, such as C. In order to test this unclamp the vernier plate and turn the instrument half round, and, *without turning the telescope over*, sight to the mark on A, and clamp the instrument in azimuth, turn the telescope over, and if the collimation is out of adjustment it will point to the position D in the figure as far to the right of B as C was to the left. This shows that the collimation of the telescope is not perpendicular to its horizontal axis. In order to correct this, measure the distance from C to D and set up a stake at the middle point B, and and another stake midway between B and D, at E. This will be one-fourth of the distance between C D, the

amount of adjustment required, and must be made by moving the vertical wire to the right or left by the capstan-headed screws y y. The telescope will then be on the line E F, both of which points are respectively equidistant from A and B, so that if the intersection of the cross-wires be accurately placed on a mark on the staff at B and turned over, it will strike the mark on the staff A, and the adjustment for collimation in azimuth will have been made; this is, however, seldom done at the first trial, and the operation has generally to be repeated. In both of these cases the adjustment has been made by the vertical wire.

Adjustment of the Telescope Level.—Level the instrument carefully on the azimuth axis H, by means of the levels d d on the horizontal limb A B; next, take a pair of verticals, *i.e.* on faces right and left, to any well-defined *terrestrial* object; set the vertical circle R to the mean of these readings, and clamp it; now intersect the object, using the two *screws* z z, *which clip* the limb of the vertical circle x, to the stud in the frames N N, and *not* the tangent-screw W; then repeat the process as before. Remember that after each pair of readings the mean is to be taken, and the object intersected by the clip-screws z z, *and not by the tangent-screw W;* and when the readings on the right face agree with the left face, the index error will be 0. Next clamp the vertical circle R at $0° \; 0' \; 0''$, and bring the bubble of the telescope level to the middle of its run by means of its adjusting screws g, and the level will be in adjustment.

With regard to the clips z z, which keep the vernier s s in position, never unscrew *both* after the adjustment has been made; but to release the vertical circle before putting the instrument into its box, unscrew only one of the clips, and mark it so that it may be known, and use this *same* screw when setting up the instrument again. The other clip-screw should never be touched; and, indeed, it would be an improvement if one of the clip-screws were fitted with a lock-nut, by which it would be kept in its proper place, and at once be distinguished from the working screw.

Adjustment of the Horizontal Limb.—Tighten the clamp-screw E, unclamp the vernier-plate A, and turn it round until the telescope is immediately over one of the parallel plate-screws I I; bring the bubble in the telescope level P to the middle of its run by turning the tangent-screw W; turn the vernier-plate 180°, so as to bring the telescope again over the same screw, but with its ends in a reverse position. If the bubble of

the telescope level does not remain in the middle of its run, bring it back to that position, *half* by one of the parallel plate-screws I I, and *half* by the tangent-screw W. This operation must be repeated until the bubble remains accurately in the centre of its run in both positions of the telescope; now turn the vernier-plate A until the telescope is directly over another of the parallel plate-screws, and bring the bubble to the middle of its run by turning *this* screw.* The bubble should now retain its position, while the vernier-plate is turned completely round, showing that the internal azimuth axis, about which it turns, is truly vertical. Clamp the vernier-plate to the lower plate by turning the clamp-screw C, and loosen the clamp-screw E; move the instrument round its azimuthal axis, and if the bubble retains its central position during a complete revolution, the external azimuth is truly parallel with the internal; when this is not the case, the instrument must be sent to the maker, as this fault cannot be remedied by the traveller.

It is most probable that the levels on the vernier-plate will now be found out of adjustment, and the bubbles must be brought to the middle of their run by turning the capstan-headed screws at the end of each of them.

Horizontality of the Axis of the Telescope.—This is to be tested by the striding-level, which is supplied with the instrument. Apply it to the pivots *y*, and if the bubble is not in the middle of its run, bring it to that position by turning the capstan-headed screws *t* under the moveable bearing. If there is no striding-level, this adjustment can be tested by observing a long plumb-line, first making the intersection of the threads in the diaphragm coincide with this line, and then, if the point of intersection moves along the line when the telescope is elevated or depressed, the adjustment is perfect; if not, it must be made to do so by turning the capstan-headed screws.

The adjustments can be tested in the following simple manner:—With the plummet supplied with the instrument, find the exact central spot over which the instrument stands; drive a peg into this place, and fasten a cord to the peg; now go in any direction, for say 40 feet, and drive in another peg, stretch the line tight between these pegs, and then intersect the line with the threads in the diaphragm, clamp the horizontal plates,

* If the theodolite is furnished with four parallel plate-screws, they must always be used in pairs.

and if the intersection remains perfect while the telescope is moved on its axis the adjustments are so far correct. Next move the outer peg about 90° (with the same radius) from its first position, and again drive it into the ground and draw the line tight as before; unclamp the vernier-plate, keeping the lower plate clamped, and repeat the previous operation; if the point of intersection of the threads in the diaphragm keeps on the line while the telescope is moved on its axis, the theodolite is in adjustment, if not, the adjustments should be gone over again.

The Vernier of the Vertical Limb.—When the foregoing adjustments have been made, set the vernier of the vertical limb to 0° 0′ 0″, and bring the bubble of the telescope level to the middle of its run by turning the clip screws. The instrument will now be in adjustment and ready for use.

All first-class instrument makers are very careful, for the sake of their reputation, to see that the theodolite is in perfect adjustment when it leaves their hands, and, with the careful treatment which this instrument should always receive, is not likely to get out of order; it is, nevertheless, necessary from time to time to test these adjustments.

Observations with the Transit Theodolite should always be taken in pairs, with the vertical circle first to the *right* and then to the *left*, and the mean of results should be taken. When a diagonal eye-piece is used for observing altitudes of the sun, the lower limb has this appearance 

and the upper limb this, 

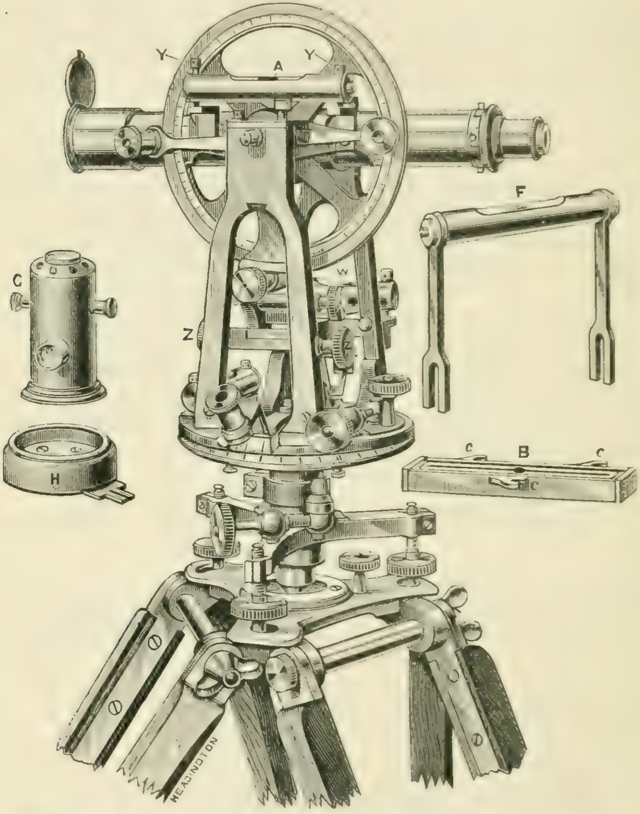
. When observing altitudes of the sun with the inverting telescope, it must be remembered that what appears to be the lower limb is really the upper, thus: 

and 

. Where the direct telescope is used the reverse is the case.

An improved form of transit theodolite, made by Elliott Bros., in which the level A is carried on the vernier arms instead of being attached to the telescope, is shown p. 116. The magnetic needle B

is also attached to the instrument in a different manner, being in all respects similar to the one used with the plane table, and is described



page 126. This is so constructed that it can be attached, by the hooks C C C, to the under part of the instrument. The adjustments of

this instrument are identical with those previously given for the more common form of transit theodolite, with the exception of that for the vernier arm level A, which is adjusted in the following manner:—First set the instrument carefully by the levels on the vernier plate, and then by means of the *clip screws* Z Z bring the bubble of the level, A, on the vernier arms to the middle of its run. Next unclamp the vertical circle and place the intersection of the hairs in the telescope, accurately, on some well-defined distant object, take the reading of the vertical circle, unclamp the instrument, turn it through 180°, turn the telescope over, again cover the object with the intersection of the telescope hairs, and take the reading of the vertical circle. The mean of these two readings (face right and face left) will be the true reading to which the vernier of the vertical arc must be set, by the tangent screw W. Then by means of the *clip screws* Z Z again cover the object with the intersection of the telescope hairs. This operation should be repeated until the reading of the vertical circle is the same with the telescope in both positions. When this has been accomplished, the bubble of the level on the vernier arms must be brought to the middle of its run by the capstan-headed screws Y Y at the end of the level-tube.

The magnetic needle is used in the following manner:—Attach it underneath the vernier plate by means of the hooks C C C provided for that purpose. Set the vernier of the horizontal plates to 360°, and then keep the upper plate clamped. Unclamp the lower plate and turn the whole instrument round until the magnetic needle points nearly to the central division in the box, clamp the lower plate, and make the needle point exactly to this division. The telescope will now point to magnetic North, and if the *upper* plate is unclamped and turned on to any object, its magnetic bearing can be read from the verniers. Care must, of course, be taken to keep the lower plate firmly clamped.

F is the striding level which can be used in levelling the transit axis. G is the lantern which is placed on the stand H after it has been fixed to the standards, and is used to illuminate the threads of the diaphragm, through the hollow axis K, when star observations are being taken.

Everest Theodolite.

This instrument has distinctive features, as shown by the figure, p. 119. The *horizontal limb* L consists of one plate only, on which the degrees are graduated; the *verniers* V are at the end of bars radiating from the centre; and another bar carries the *clamp* C and the tangent-screw for the verniers. At S, are shown the *clamp* and *slow-motion screw* of the horizontal limb. The vernier bars are connected with the upper portion of the instrument carrying the *telescope* N N, and *vertical limb* M M, which, turning upon the same centre, show the angle traversed by the telescope.

The tripod support B is provided with *foot screws p p p*. It will be seen by the figure that the telescope and vertical limb are supported in a manner very similar to the transit theodolite, the horizontal axis connected with the telescope resting on two supports Y, only one of which is seen in the drawing. These are supported by a flat horizontal bar E, to which is attached a spirit level, only one end of which is seen in the drawing. This level is for adjusting the axis horizontally; and, this being accomplished, the vertical arc M M, attached to the telescope, moves with it in a vertical plane.

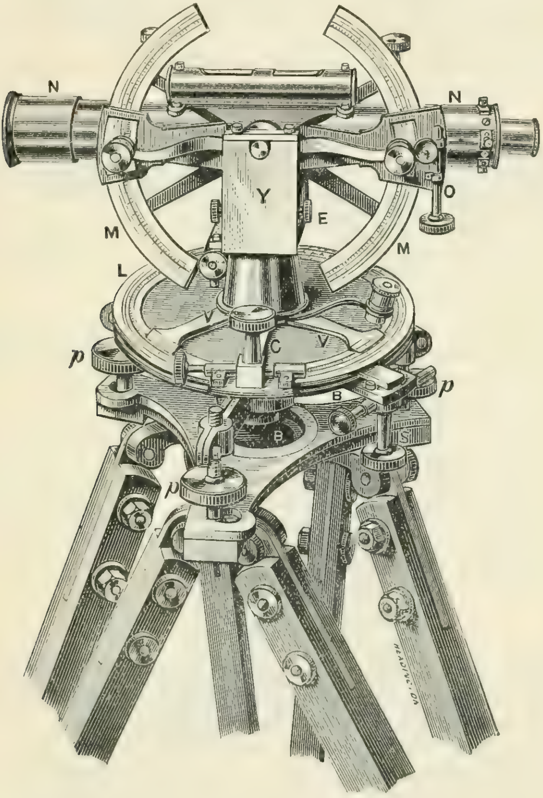
Adjustments of Everest Theodolite (*furnished by Captain Pratt, R.E.*).

1. *Correction for Parallax.*—Adjust the eye-piece to distinct vision of cross hairs, and correct for parallax by means of the object-glass screw.

2. *Making the Level of the Horizontal Limb parallel to that Limb.*—Clamp the tribrach to axis, and unclamp the horizontal vernier-plate Move the latter so that the horizontal limb's level may be over, or parallel to, two foot-screws. By means of these screws bring the bubble to the centre of level. Turn the vernier-plate round 180°, and correct the level's error half by the foot-screws and half by the level's capstan-headed screws. Turn the vernier-plate back to its original position; and if the bubble is not now exactly in the centre, correct as before. Repeat the process till accuracy is obtained.

3. *Levelling the Instrument, i.e., making its vertical axis truly vertical.*—Clamp the tribrach to axis, and unclamp the horizontal vernier-plate. Level the horizontal limb's level by the foot-screws. Turn the horizontal

vernier-plate round 90° and re-level. This will make the vertical axis approximately vertical. Then bring the bubble of the vertical limb's



level to the centre of tube by the two antagonising screws at bottom of vertical vernier-plate. Turn round 180°, and if the vertical limb's level is disturbed, correct half of the error by the foot-screws and half by the

two antagonistic screws. Turn the horizontal plate 90°, and repeat the process till accuracy is obtained.

If the bubble of the level attached to the horizontal plate is now disturbed, bring it to centre of tube by the capstan-headed screw, so as to make it an index of horizontality.

4. *Vertical Collimation.*—Unclamp the vertical limb, and make its level horizontal by means of the antagonising screws. By means of the vertical limb's tangent-screw get the horizontal spider-line to cover some well-defined distant point. Read off the angle on the vertical verniers.

Reverse the instrument on its bearings, re-level, and re-intersect the same object. If now the vertical verniers read as at first, the vertical collimation is correct. If not, the mean of the readings is the true angular deviation from the horizontal. By means of the vertical limb's tangent-screw make the vertical verniers read this true deviation, and intersect the distant point by means of the antagonising screws.

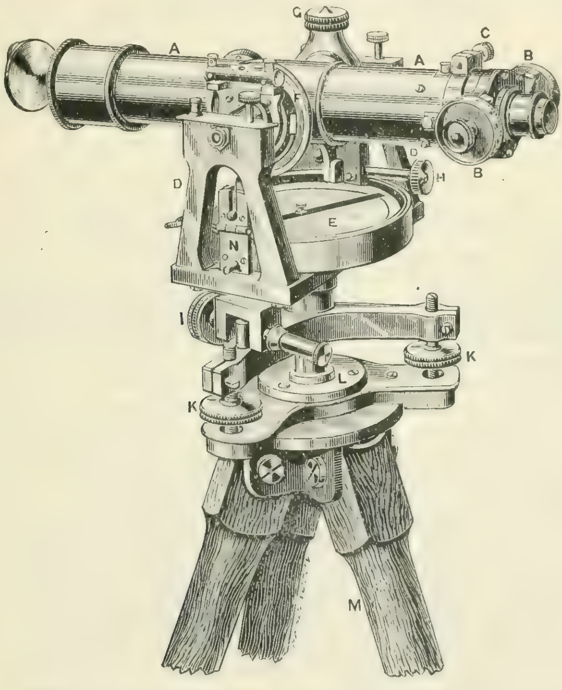
This will disturb the level of the vertical limb. Restore its horizontality by means of the capstan-headed adjusting screws. The verniers should now read the same angle in both positions of the transit axis. If not, repeat the process till accuracy is obtained.

5. *Horizontal Collimation.*—Intersect some well-defined distant point with the spider-lines. Reverse the instrument on its bearings. If there is any deviation from the intersection, correct half with the tangent-screw of the horizontal limb and half with the capstan-headed screws which move the diaphragm. Reverse the instrument on its bearings, and repeat similar corrections till accuracy is obtained.

Tacheometer.

A Tacheometer is an instrument for measuring small angles. Of many different types of tacheometers in use by surveyors the form adopted by the Indian Government and made by Messrs. Troughton & Sims is best suited to meet the requirements of the traveller. It consists of a *telescope* A, fitted with a pair of *micrometers*, B B, which are used for measuring either vertical or horizontal angles, as they can be turned through an angle of 90°, and fixed in that position by the *screw* C. The telescope is mounted on *standards* D D, over a *prismatic compass* E, and is furnished with a *small circle*, F, for taking vertical angles, which

can be read to minutes. G is the screw by which it is clamped in altitude; H is the *vertical slow motion screw.* The instrument is fitted with a screw (not shown in the plate) for clamping it horizontally, and I is the *horizontal slow motion screw.* The bearing of any object is read through the *prism* N. There are three *levelling screws,* K, which fit into a



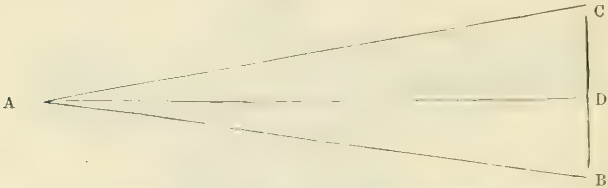
tribrach L, that screws on a *tripod* M. The instrument is levelled by means of the screws K, and a level attached to one of the standards (not shown in the plate).

There is a disc of glass visible in the field, divided in such a manner that each division equals one revolution of the micrometer head, and

each micrometer head is divided into 100 parts. These divisions are both vertical and horizontal, to suit the corresponding positions in which the micrometers are used.

The measurement of distances by means of the tacheometer is based on the solution of a triangle:—

Fig. 1.



In Fig. 1, suppose the instrument to be at A, and a staff of known length to be represented by BC; then if the angle BAC is measured, and the length of the staff BC is known, the distance AB can be easily computed. In order, however, to measure the angle BAC, the value of the micrometer divisions must be determined in the following manner:—Carefully measure the distance AD from the instrument to a staff of known length; measure the angle BAC subtended the staff with each micrometer, carefully noting the number of divisions and decimals of a division used with each. Divide the length of the rod by the distance AD between the instrument and the rod, and multiply this by the cosecant of 1″ = 206265, and the result will be the value of the angle BAC in *seconds* as measured by that micrometer. Now divide BAC in *seconds* by the number of micrometer divisions used in taking it, and the result will be the value of each division of the micrometer in seconds and decimals of a second. As the value of the divisions will not be exactly the same in both micrometers their values must be separately determined.

Example:—Number of divisions used (Right Micrometer), 1157·1; length of rod, 12 feet; distance between rod and instrument, 983·2 feet.

Log 12 = 1·079181	″
Log distance 983·2 = 2·992642	1157·1) 2517·460 (2·17 { Value of each division.
	23142
$\bar{2}$·086539	20326
Cosecant of 1″ = 206265 Log = 5·314425	11571
The whole ∠ = 2517·″46 = Log 3·400964	87550
	80997

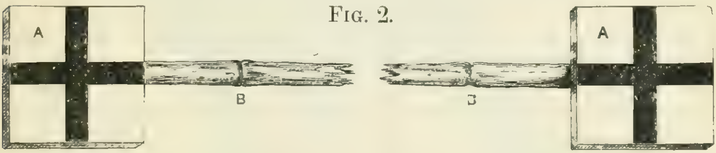
The same process would have to be gone through to find the value of a division of the Left Micrometer.

In combination with this instrument a rod of known length is generally used. Fig. 2 represents such a rod. A A are two boards, one foot square, painted white, with a black cross on each. These are fastened on a bamboo, B B, in such a manner that the centres of the crosses shall be a known distance apart.

When using the rod in a vertical position it will often be found convenient to fasten a stick to it, so that it shall extend about two feet beyond one of the boards. This, when placed on the ground, takes the weight off the rod and helps the assistant to keep it steady.

Any theodolite can be used as a tacheometer, by having hairs in the diaphragm fixed at such a distance apart as to read one foot on a staff when it is one hundred feet distant from the instrument, two feet when

FIG. 2.



the staff is two hundred feet distant, and so on, and a theodolite fitted in this manner will always give a proportion of 1 to 100 between the reading on the *graduated* staff and the distance. As the power of the telescope is usually small, the figures and marks on the graduated staff can only be read at a comparatively short distance.

The following precautions must be taken, or no accurate results can be obtained. The fixed hairs must be adjusted to read in the proportion of 1 to 100, or, what is the same thing, the staff must be marked to read one foot, when it is 100 feet distant from a certain point. It is the determination of where this point is that is absolutely necessary, and the place from which to measure the distance is arrived at in the following manner:—Mark the ground immediately under the centre of the instrument by dropping the plummet from the centre of the tripod, in the usual manner, and from this measure a distance, in the direction the telescope points, equal to the focal length of the object-glass, added to the distance from

the object-glass to the vertical centre of the instrument. Thus, if the focal length of the object-glass was 12 inches, and the distance of the object-glass from the vertical centre of the instrument was 7 inches, then the position of the point from which to commence the measurement of the 100 feet would be 19 inches from the place where the plummet let fall from the centre of the tripod touched the ground.

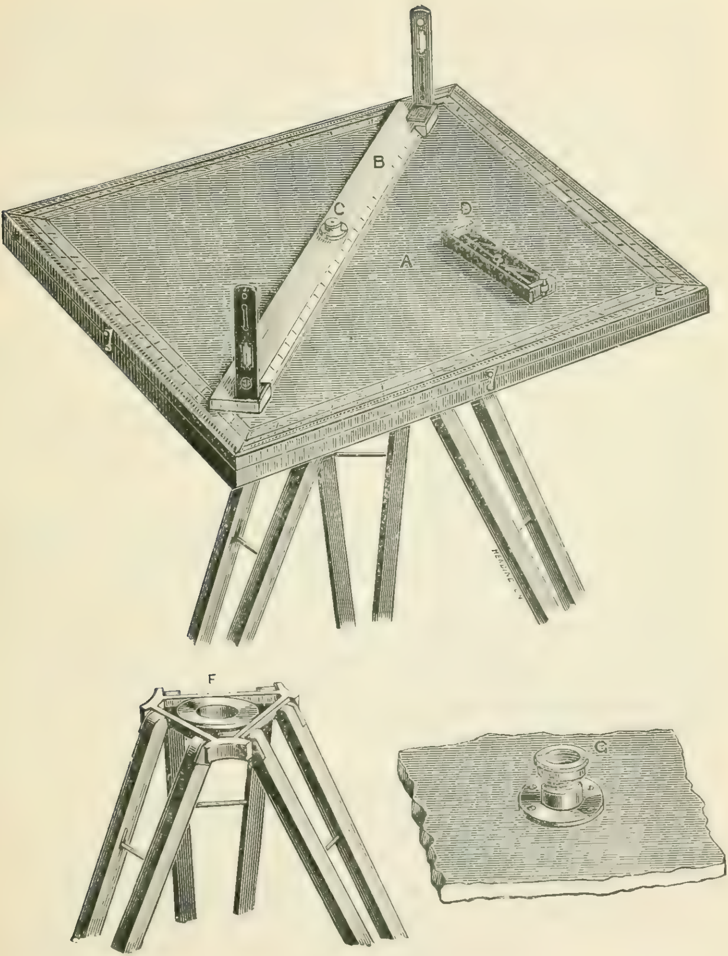
To all distances measured in this manner a constant, equal to the focal length of the object-glass + the distance of the object-glass from the vertical centre of the instrument, must be added, otherwise there will be an increasing error in each distance that is measured. (*For instructions for using this instrument in the field, see p.* 185.)

The Plane Table.

The plane table is, in substance, a drawing board fixed on a tripod, so that lines may be drawn on it by a ruler placed so as to point to any object in sight. Its advantage is, that it enables a survey to be made without the aid of other instruments, and in less time.

All its other parts are mere additions to render this operation more convenient, and accurate. Though the principle on which all plane tables are constructed is the same, they vary considerably in detail. Those, for instance, used by the United States Coast Survey, and several of the European Governments, are very elaborate instruments, fitted with parallel plates and levelling screws, having also a telescope in the place of the ordinary sights. The plane table then becomes an instrument of precision, but is much more liable to sustain injury from accident than in its rougher form, not more so, however, than a theodolite or sextant. The levelling screws enable the traveller to set up his instrument much more expeditiously and accurately than he possibly could without them, and with the telescope he will be able to see distant objects that would otherwise be too indistinct to be made use of in the survey.

The Table.—A is a rectangular board of well-seasoned wood, and can, within certain limits, be made of any size to suit the work intended to be done. To this board the paper to be drawn on may be attached either by drawing-pins, clamping-plates, or a *box-wood frame*, E, which is usually graduated in the same manner as a protractor, and can be used to



Plane Table.

measure horizontal angles, when the fiducial edge of the ruler is placed against a pin in a small hole, in a brass plate in the centre of the table, which is provided for the purpose. A stud, on the under part of the table, fits into a socket in the *tripod*, F; the table can then be revolved to any horizontal position, and there fixed by tightening the large *nut*, G, on the clamping-screw attached to the stud.

The Tripod, F, should be a split one, and for convenience of packing the legs should telescope. This arrangement is also convenient for setting up the instrument on sloping ground. The screws for tightening the tripod legs should be enlarged at the end so as to prevent their falling out. In many cases it will be convenient to have the plane-table tripod so made that it can be used for the other instruments.

The Alidade, B, is a flat ruler, having a fiducial edge, each end of which carries a sight-vane. On the centre of the ruler is a small *circular level*, C, to be used in setting up the table. In mountainous countries a small telescope fitted on the alidade will be found very convenient, and where this is not the case, the sight-vanes should be made considerably longer than would be necessary if the instrument had to be used in a comparatively level country.

The Compass, D, should have a needle about four inches long, contained in a rectangular metal box, and is sometimes so arranged that when the needle points to north it will be parallel to the outer straight edge of the box.

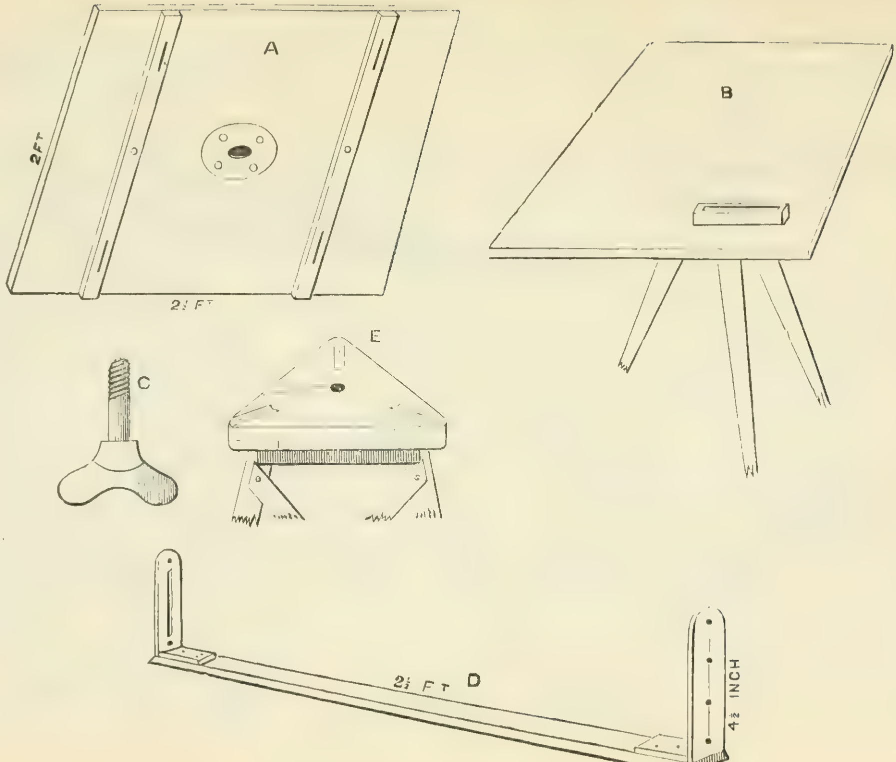
A pair of compasses, paper, india-rubber, pencils, a pen-knife, and some pins, complete the essentials for plane-table work.

It is not considered necessary, in these "Hints," to give any detailed description of the more elaborate forms of the plane table, but any person desiring information on the subject can obtain it by applying to the Instructor at the Society's rooms. (*For instructions for using this instrument in the field*, *see p.* 173.)

Plane Tables used in the Indian Survey Department.
By Lieut.-Col. H. H. Godwin-Austen.

A. View of under part of the plane table, showing the brass plate in the centre with socket-screw, counter-sunk and fixed by screws.

The board should be one inch thick, of well-seasoned wood—deal is the lightest. Two bars are attached across the grain to prevent warping,



The Indian Plane Table.

SPECIMEN
of a portion of
PLANE TABLE WORK
IN PROGRESS
to show method of taking and securing rays observed.

FORM FOR FIELD BOOK.

Date.	Number on Plane Table.	NAME OF PLACE.	Number of Houses.	Lat. °	'	"	Long. °	'	"	Observations for Altitude. Time.	No. of B. P. Ther.	Boiling Point Ther.	No. of Air Ther.	Thermom.	No. of Aneroid.	Aneroid or Barometer.	Deduced Height.	REMARKS.
1864	47	Am Mochu ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	River from Chumbi and Phag Rhi.
											15	206·60						
5th Feb.	48	Mochu Bridge.	..	..	..	..	..	..	..	3 P.M.	6	206·18	4	65	..	..	3849	
											11	206·20						
	49	Waterfall ..	..	..	..	..	..	..	..									
	50	Muchu	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Stream joining Am Mochu.
	51	Pètso	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Peak high to south.
6th Feb.	52	Tsangbè Camp	..	..	..	..	..	..	..	4 P.M.	15	202·6	4	50·5				

fixed by one screw in the middle, with two at each end, working in a long hole so as to allow of expansion and contraction. The screws should be bevelled at the shoulder, and a slip of brass should be placed between the shoulders of the screw and the wood to prevent counter-sinking.

B. View from above, as placed on the tripod-stand, with compass-box in position. The stand is similar to that used for the photographic camera, having folding legs and a triangular top of wood with a hole in the centre for the clamping-screw, C, to pass through. A solid tripod-stand, as shown in E, is, however, the best, and can be made very light and strong, and it can be used when observing with the theodolite.

D is the sight-rule—as long as the plane table—and packs inside the waterproof case. The back sight has a narrow slit cut in it; the fore sight has a wider slit, with two small holes above and below to receive the horse-hair or fine wire, which is easily adjusted and retained in position by little pegs of wood.

Watches.

The keyless half-chronometer is the most suitable watch for a traveller in wild countries. (The half-chronometer watch is a lever watch, with compensation balance, and a carefully-tempered pendulum spring.)

The ordinary pocket chronometer is expensive, and not calculated to stand the rough usage to which most travellers' watches are subjected. The objections to it are: (1) The extreme delicacy of the escapement and liability to injury from rust or accident. (2) Its great liability to stoppage from various causes, such as a sudden jerk when riding or travelling over a rough country; even if in the act of winding it the holder should inadvertently give a circular motion to his hand in a direction opposite to that in which the balance-wheel is moving at the same instant, it may stop. (When a chronometer is once stopped it will not start again unless a circular motion be given to it.) (3) The impossibility of its repair when injured, except by high-skilled workmen, and when very slightly injured, the consequent great disturbance and irregularity in its rate.

Under favourable circumstances, and in skilled hands, pocket chronometers have done good service, but this is exceptional. The minimum price of a good pocket chronometer, in a silver case, is 45*l*.

Half-chronometers are not liable to stop from the before-mentioned causes, and they are more easily repaired. They may be carried in the pocket under conditions of rough usage, short of actual violence, and under ordinary circumstances their performances are frequently but little inferior to those of a chronometer at rest.

During the last thirty years, great improvements have been made in the manufacture of the lever escapement, compensation balances, and the pendulum springs, upon which the ability of a watch to keep a steady rate in a great measure depends. The keyless mechanism has also been perfected, and it is not necessary to open the case of a keyless watch in order to wind it; thus the works receive increased security from dust and damp, the two great enemies of all time-pieces.

The following is the description of such a watch as would be best suited to a traveller. The watch should be a 16-size half-chronometer; the bezel (or frame which holds the glass) should have neither hinge nor spring, but should fit very closely over the watch-case, and snap tightly when pressed home; great care should be taken to see that the marking of the minutes on the dial is correct, so that in whatever part of the hour circle the minute hand shall point to a division, the seconds hand shall at the same time point to 0. This perfect coincidence for the whole circle of the dial is by no means common; its absence is chiefly due to eccentricity in fixing the dial-plate, and the error is often so great as to be a cause of annoyance to the traveller, who will have frequent difficulty in deciding as to which minute the seconds belong. The seconds dial-plate should be sunk, and the glass should be thick flat crystal. A good watch of this kind cannot be purchased for less than 20*l*.

The keyless watch has many advantages over the old form, of which the following are some:—It cannot be wound the wrong way. It cannot be over-wound, and the case has not to be opened for winding. When the glass and back are made to screw on, and the winding-button is fitted with a screw cap, a watch of this kind has been placed in water, and proved impervious to damp after several hours'. immersion. Should the winding mechanism get out of order, the watch can be wound with a common key in the same manner as an ordinary watch. The cost of a good watch of this description is 37*l*.

Care should be taken to wind a watch at about the same hour every

day, and as nearly as possible to subject it to the same daily treatment with regard to its position in the pocket, or the place where it is laid down at night.

In purchasing a watch be sure to go direct to the manufacturers, and see that it has an "A" certificate from Kew Observatory. Such watches as those mentioned can only be obtained of the best makers. Cheaper watches, purporting to have compensation balances, and the best pendulum springs, may be obtained from many shops; but it will often be found (when too late to replace them) that they are not all they profess to be, that they have never been properly adjusted, and are, in consequence, so affected by change of position and temperature, as to be useless for scientific purposes.

SURVEYING AND ASTRONOMICAL OBSERVATIONS.

Part 2.

Plane Trigonometry and Preliminary Remarks.

The following formulæ are of frequent use in all surveying problems. In right-angled triangles, B being the right angle, if either A or C is known, the other is found by subtracting the known angle from 90°. For the rest we have:

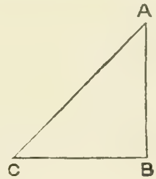


Table I.

Case.	Given.	Required.	Solution.
1	Hyp. A C Angles ..	Base C B.. Perp. A B	$CB = AC \times \cos C$. $AB = AC \times \sin C$.
2 & 3	Base C B Angles ..	Perp. A B Hyp. A C	$AB = CB \times \tan C$. $AC = CB \times \sec C$.
4 & 5	Hyp. A C Perp. A B	Angles .. Base B C	$\sin C = AB \div AC$; $\cos A = AB \div AC$. $BC = \sqrt{(AC + AB) \times (AC - AB)}$.
6	Perp. A B Base B C	Angles .. Hyp. A C	$\tan C = AB \div BC$; $\cot A = AB \div BC$. $AC = BC \times \sec C$.

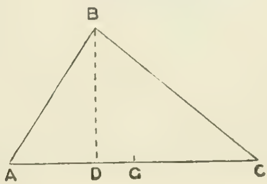


TABLE II.

Case.	Given.	Required.	Solution.
1	The angles and side A B.	Side B C Side A C	$BC = AB \times \sin A \times \operatorname{cosec} C$. $AC = AB \times \sin B \times \operatorname{cosec} C$.
2 & 3	Two sides A B, B C, and angle C opposite to one of them.	Angle A Angle B Side A C	$\sin A = \sin C \times BC \div AB$. $B = 180^\circ - (A + C)$. $AC = AB \times \sin B \times \operatorname{cosec} C$.
4 & 5	Two sides A B, A C, and the included Angle A.	Angles C and B Side B C	$\tan \frac{B - C}{2} = (AC - AB) \times \cot \frac{A}{2} \div (AC + AB)$. and, $\frac{B + C}{2} = 90^\circ - \frac{A}{2}$: from which $B = \frac{B + C}{2} + \frac{B - C}{2}$: and $C = \frac{B + C}{2} - \frac{B - C}{2}$. $BC = AB \times \sin A \times \operatorname{cosec} C$.
6	All three sides.	All the Angles	From half the sum of the three sides, subtract, separately, each of the three sides. Multiply these four numbers (the half sum and the three remainders) together, and take twice the square root of the product. This result, divided by the product of any two of the sides, gives the sine of the angle between them.

In oblique-angled triangles, if two of the angles are known, the third angle is found by subtracting the sum of the two from 180°; for the rest *See* Table II.

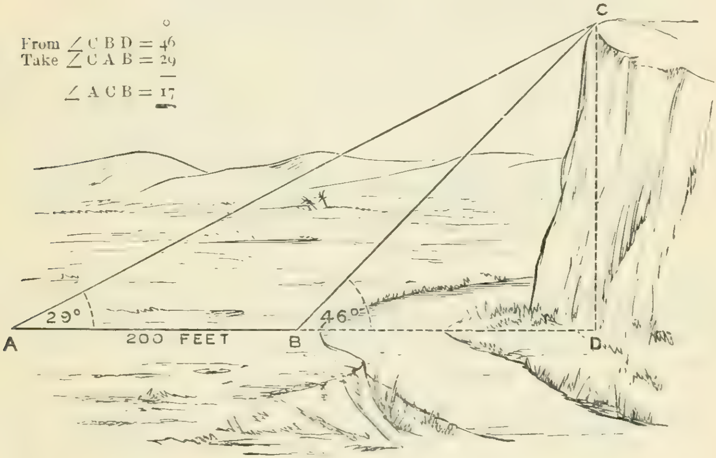
The foregoing equations may be solved by multiplication and division, with a table of natural sines, cosines, &c.; but, in order to avoid such a tedious process, logarithms are usually employed. In calculating with logarithms, multiplication is performed by adding together the logarithms of the numbers to be multiplied: the sum is the logarithm of the product: division is performed by subtracting the logarithm of the divisor from the logarithm of the dividend; the remainder is the logarithm of the quotient. *Twice* the logarithm of a number is the logarithm of its square; and *half* its logarithm is the logarithm of its square root.

The following are some of the most useful examples of the practical application of the rules given in Tables I. and II.

(1.) Wishing to ascertain the height of a point C (Fig. 1), which could not be approached nearer than B, I observed the angle of altitude C B D = 46°, and measured the distance from B to A = 200 feet, at which place I found the angle C A B = 29°.

Having found the ∠ A C B as above, I then computed the length of B C by *Case* 1, *Table II.* Then, as the ∠ C D B = 90°, I computed the height C D by *Case* 1, *Table I.*

FIG. 1.

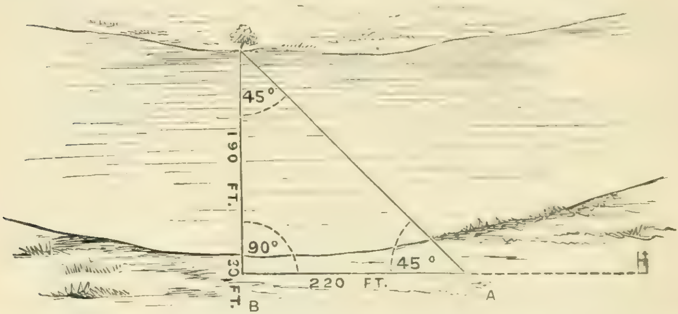


(2.) To measure the breadth of a river when standing at B (Fig. 2), a short distance from it, I sent on a man with a staff to a distance which I judged to be greater than the breadth of the river. I then motioned him to the right and left until he was in such a position that the reflected image of the staff was shown exactly over a tree on the opposite bank (as seen directly), when I had 90° on the arc of my sextant: having set my sextant to 45°, I walked in a straight line towards the staff until I reached a position, A, where, on looking through my sextant, I saw the reflected image of the tree shown exactly over a mark set up at B (as seen directly). I then measured the distance from A to B, which I found to be 220 feet;

from this I subtracted 30 feet, the distance of the water, and this gave me the breadth of the river, 190 feet.

(3.) In order to measure the breadth of a river I set up a mark, A (Fig. 3), close to the water; from this point I measured a base of 200 yards,

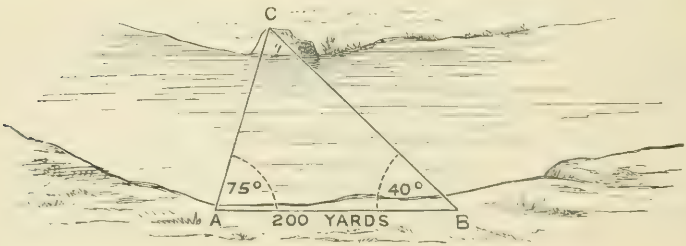
FIG. 2.



parallel to the course of the river, and set up another mark, B. The angles, subtended by a rock on the opposite bank and each end of the base, were A 75°, B 40°. I then computed the breadth of the river by *Case* 1 *Table 11.*

$$\begin{array}{lr} & ^\circ \\ \angle A & 75 \\ \angle B & 40 \\ \hline & 115 \end{array} \qquad \begin{array}{r} ^\circ \\ 180 \\ 115 \\ \hline \angle C = 65 \end{array}$$

FIG. 3.



(4.) To ascertain the height of an inaccessible point, A (Fig. 4), above my position C, I measured its angle of elevation with a theodolite, and

FIG. 4.

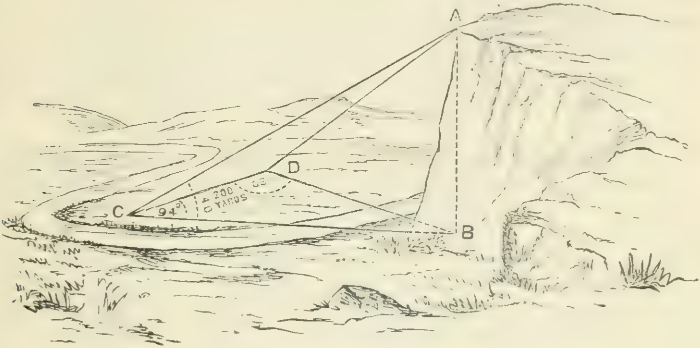
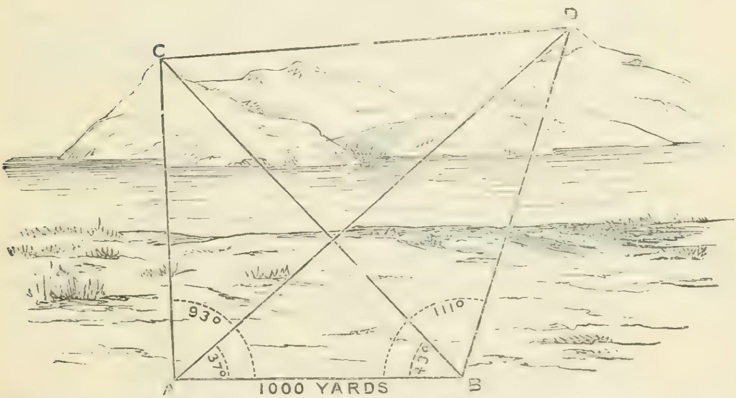


FIG. 5.



found it to be 40 : as a river behind me prevented my taking a base in that direction, I measured one of 200 yards to the left of C and set up a

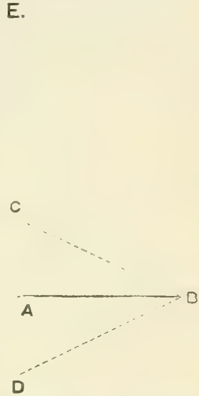
mark D. The angles subtended by A, at each end of the base, were found to be, C 94°, D 63°; with these angles and the base C D, I computed the side B C by *Case* 1, *Table II.* Then, as BC is the base of the right-angled triangle A B C, I computed the height of the A by *Case* 2, *Table I.* Should a sextant be used, the angles A C D and A D C will be taken, and with these, and the base C D, compute the side A C by *Case* 1, *Table II.* Then as A C is the hypothenuse of the right-angled triangle A B C, the height of the point A can be computed by *Case* 1, *Table I.*

(5.) The distance between two inaccessible peaks C and D (Fig. 5) being required, I measured a base, A B, of 1000 yards, setting up a mark at each end. I then measured the angles between the two peaks, at both ends of the base, and found them to be:—at A, 37° and 93°; at B, 43° and 111°. In the triangle A B C, by subtracting the sum of angles A and B, = 136°, from 180°, I found the angle C to be 44°; by a similar process I found the angle D in the triangle A B D to be 32°, and in the triangle B C D, by subtracting 43°, the smaller angle, from 111°, the greater, I found the angle at B = 68°. Having thus found all the necessary data in the triangle A B C, I computed the side C B (*Case* 1, *Table II.*), and in the triangle A B D, I computed the side D B (*Case* 1, *Table II.*). With the sides C B and B D, of the triangle B C D and the included angle B, I computed the side D C (the distance between the inaccessible peaks) by *Cases* 4 and 5, *Table II.*

Extemporary Measurements.

To set off a Right Angle from any point on the ground by means of a Rope.

To set off from any point A, a line at right angles to a given direction, as A E, measure an equal distance on each side of A, in the same straight line as A E, this equal distance *being about one-fourth of the length of the rope.* Let C and D be these points. Fasten the ends of the rope at C and D, and having ascertained the centre of the rope by doubling it, the centre should be drawn out towards B, until D B and C B are tight. Then E A B will be a right angle; therefore, as we are thus able to set off a right angle to any line, the distance of any inaccessible object may be obtained by either of the three following ways:—



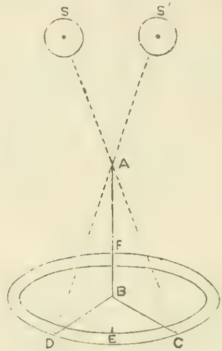
To find the Meridian by a Watch.

When the sun is visible, the position of the meridian line can be approximately determined in the following manner by a watch set to local time:—Turn the face of the watch to the sun in such a manner that the hour-hand shall point to the sun, or, in other words, until the hour-hand itself shall be directly over its shadow. Half-way between the place of the hour-hand and XII. will be the south point in north latitude, and the opposite point of the dial will be the north point. In south latitude the reverse of this would be the case, while in the tropics the position of the north and south points would depend on whether the sun, when on the meridian, is north or south of the observer. When the sun is near the zenith this method would be of little use.

To find the Meridian by the Sun, without instruments.

Having levelled a piece of ground of sufficient size, plant a rod in a truly perpendicular position, testing it with a plumb-line, and at an hour or two before noon (say 10.30) mark accurately the extremity, C, of the

shadow, B C, thrown by the rod when the sun is in the position S; then from the base, B, of the rod as a centre, with the radius B C, the length of the shadow, describe the circle, D C F, upon the ground. As the sun's altitude increases, the shadow of the rod will fall within the circumference of the circle, and will gradually grow shorter until noon; after which, as the sun's altitude decreases, the shadow of the rod will grow longer until, at last, when the sun has attained the position S′, it will



reach the circumference of the circle at the point D. Divide the arc C D, into two equal parts, and from E, a point equi-distant from C and D, draw a line through the centre B, and that line will coincide, approximately, with the true meridian.

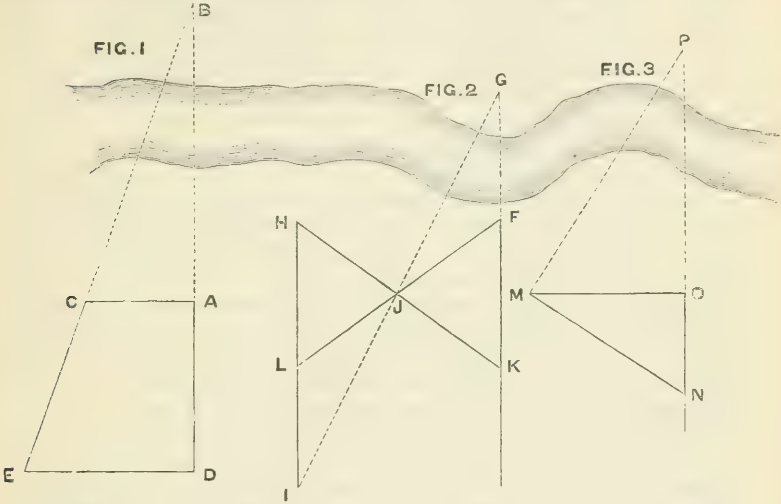
To find the Distance of an inaccessible object with a Measuring Line.

By Fig. 1, p. 141.—From the line A D measure off the perpendiculars A C, D E, ranging the point C in line with E B, then

$$A\,B = \frac{A\,C \times A\,D}{D\,E - A\,C}.$$

By Fig. 2, p. 141.—Fix any convenient points H and K. Join H K and bisect it in J; make J L = J F, and range I in line with H L and with J G; then L I = F G.

By Fig. 3.—Set off O M at right angles to O P, and M N at right angles to M P; then $O\,P = \dfrac{O\,M^2}{O\,N}$.



Rough Methods of Measuring.

Rough angular measurements may be taken by the span at arm's length. From the end of the thumb to the end of the middle finger subtends an angle of 15°; the full span to the end of the little finger subtends an angle of 18°. This may be easily checked by spanning round the horizon; twenty spans make the circuit. It is at all times well to know the length of the different joints of the limbs. Suppose the nail-joint of the forefinger to be 1 inch, the next joint will be $1\frac{1}{4}$ inches, the next 2 inches, and from the knuckle to the wrist 4 inches; in this case the finger is bent, so that each joint may be measured separately, though, when held straight, the distance from the tip of the forefinger to

the wrist would be only 7 inches. The span with thumb and forefinger would be 8 inches, and with the thumb and any of the other three 9 inches, or equal to the length of the foot; from the wrist to the elbow would be 10 inches, and from elbow to forefinger 17 inches, and from collar-bone to forefinger 2 feet 8 inches; height to the middle of the kneecap 18 inches. From the elbow to the forefinger is usually called a cubit, but it is seldom strictly so, an English cubit being generally stated as 18 inches. In like manner the full stretch of the extended arms is called a fathom; but it is generally somewhat less.

The pace is commonly supposed to be $2\frac{1}{2}$ feet, but this is a most uncertain mode of measurement. Very few men, *without practice*, can take correctly a hundred consecutive steps or paces of the same length. Practice will determine the amount of ground covered in a certain number of paces, if tried over known distances; it of course varies, but from experiment the mean has been found nearly as follows:

Pacing, at 30 inches per pace, of 108 in a minute, equals 270 feet, or 3·068 statute, or 2·66 geographical miles per hour.

Pacing quickly, at 30 inches per pace, of 120 in a minute, equals 300 feet, or 3·41 statute, or 2·96 geographical miles per hour.

Pacing slowly, at 36 inches, may average 60 per minute, equals 180 feet, or 2·04 statute, or 1·78 geographical miles per hour.

The height of a tree, or other accessible object, may be found approximately by walking away from it, until, with your back to the tree, by bowing your head down as far as you can, and looking between your legs, the tree top is just seen; then pace the distance to the tree, and this will be its height. This method is in common use in the logging camps of North-West America, and from constant practice the backwoodsman will tell to a few feet how far the top of a tree, he is going to cut down, will reach. The legs must be kept straight, and only sufficient space left just to see between them.

Distance by Sound.

Sound travels at the rate of about 1090 feet in one second in calm weather and temperature 32° Fahr., and increases at the rate of 1·15 foot for each degree of temperature above 32°; a moderate breeze accelerates or retards sound by about 20 feet in a second. When a gun is used

to measure distance it should always be pointed at an angle of about 45° to the horizon. This method will be found most useful in making rough surveys of winding rivers or lakes, where it is impossible to land on account of the dense undergrowth or the swampy nature of the banks. Great accuracy may be obtained if a gun is fired at each end. A base for a small triangulation can be measured by this means.

Table for Rough Triangulation without the usual Instruments, and without Calculation. *By* Francis Galton, F.R.S.

A traveller may ascertain the breadth of a river, or that of a valley, or the distance of any object on either side of his line of march, by taking about 60 additional paces and by making a single reference to the Table on page 144.

Suppose he is travelling from A to Z (Fig. I., p. 144), and wishes to learn the distance from A to C; and it may be, also the angle A. Let him proceed as follows (referring now to Fig. II.).

1. Leave a mark at A. 2. Walk ten paces towards Z, and make a mark, calling the place *m*. 3. Walk back to A. 4. Walk ten paces towards C. 5. Walk to *m*, counting the paces to the nearest half-pace. (This gives the measurement of the line *a* (Fig. I.), which is the chord of the angle A, to radius 10.) 6. Walk 80 paces towards Z; make a mark, calling the place *n*. 7. Walk ten paces towards Z, calling the place B; this completes 100 paces from A. 8. Walk ten paces towards C. 9. Walk to *n*, counting the paces to the nearest half-pace. (This gives the line *b*, which is the chord of the angle B, to radius 10.)

Now enter the Table with *a* at the side and *b* at the top, and read off the distance A C, and the angle A if also required.

If the Table be entered with *b* at the side and *a* at the top, it gives B C (and B).

Of course, the units need not be paces: feet, furlongs, miles, hours, journey, or anything else will do as well; and the units of A B need not be the same as those of *a* and *b*. Also any multiple or divisor of 100 for A B may be used, if the tabular number be similarly multiplied.

TABLE for Rough Triangulation without the usual Instruments and without Calculation. By FRANCIS GALTON, F.R.S.

	ANGLE.	5 ○	5 ½	6 ○	6 ½	7 ○	7 ½	8 ○	8 ½	9 ○	9 ½	10 ○	10 ½	11 ○	11 ½	12 ○	12 ½	13 ○	13 ½	14 ○	14 ½
5 ○	28° 58'	57	60	64	67	70	73	75	78	81	84	87	89	92	95	98	101	105	109	113	118
½	31 56	55	59	62	65	69	72	74	78	81	84	87	90	93	96	100	103	107	112	116	122
6 ○	34 56	54	57	61	64	68	71	74	77	80	84	87	90	94	97	101	105	110	115	120	126
½	37 56	53	56	60	63	67	70	74	77	80	84	87	91	95	99	103	108	113	119	125	132
7 ○	41 0	52	55	59	63	66	70	73	77	81	85	88	92	96	101	106	111	117	123	130	139
½	44 4	51	55	58	62	66	70	73	77	81	85	89	94	98	103	109	114	121	128	136	146
8 ○	47 10	50	54	58	62	66	70	74	78	82	86	91	95	101	106	112	118	125	134	144	156
½	50 20	49	53	57	61	65	70	74	88	83	88	92	98	103	109	116	123	132	141	153	
9 ○	53 30	49	53	57	61	66	70	75	79	84	89	94	100	106	113	121	129	139	150		
½	56 4	49	53	57	62	66	71	76	81	86	91	97	103	110	118	126	136	147			
10 ○	60 0	48	53	57	62	67	72	77	82	88	94	100	107	115	123	133	145				
½	63 22	48	53	58	63	68	73	78	84	90	97	104	112	120	130	141	154				
11 ○	66 44	49	53	58	64	69	74	80	86	93	100	108	117	127	138						
½	70 12	49	54	59	65	70	76	83	89	97	105	113	124	135	147						
12 ○	73 46	50	55	60	66	72	79	85	93	101	110	120	131								
½	77 22	50	56	62	68	75	81	89	98	106	117	128	141								
13 ○	81 6	52	57	64	70	77	85	93	103	113	125	138	155								
½	84 56	53	59	66	73	81	90	99	109	121	135	150									
14 ○	88 52	55	62	69	77	85	95	106	118	132	148										
½	92 56	57	65	73	81	91	102	114	129	145											
15 ○	97 10	60	68	77	87	99	110	126	143												
½	101 36	64	73	83	95	108	123	141													
16 ○	106 16	69	79	90	105	121	140														
½	111 [illegible]	76	88	103	120	141															

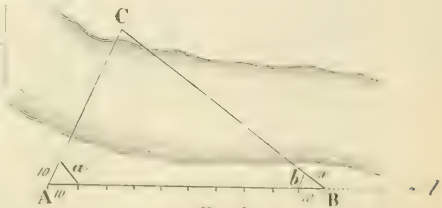


FIG. I.

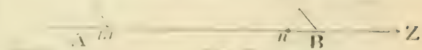


FIG. II.

To find A C and angle A:—Enter with a at the side and b at the top.   To find B C and angle B:—Enter with b at the side and a at the top.

EXAMPLES.

a (in paces).	b (in paces).	A B.	A C.	Angle A.	B C.	Angle B.
				° ′		° ′
5	6½	100 paces	67 paces	28 58	53 paces	37 56
5	6½	50 miles	33½ miles	28 58	26½ miles	37 56
10½	7	100 paces	68 paces	63 22	92 paces	41 0
10½	7	1000 paces	680 paces	63 22	920 paces	41 0

Particular care must be taken to walk in a straight line from A to B. It will surprise most people, on looking back at their track, to see how curved it has been, and how far B n is from pointing truly towards A. It is important to sight some distant object in a line with Z when walking towards it.

The triangle A B C must be so contrived that none of its angles are less than 30°, or the chords of the angles at A and B will not be found in the Table. These cases cease to give reliable results when the measurements are rudely made, and have therefore been omitted.

Should a traveller have no Tables by him, he can always *protract* his measurements to a scale on a sheet of paper, or even on the ground, and so solve his problem. If real accuracy be aimed at, it is clear that it may be obtained by careful measurements of the base and chords, combined with a rigorous calculation, as was first suggested by Sir George Everest, formerly Surveyor-General of India. (See 'Journ. R. Geog. Soc.,' 1860, page 122.)

Ascertaining Heights by Angles of Elevation.

When using an angle of elevation to ascertain the difference of height of a mountain top and the position of the observer, it must be recollected that, if at any distance, a large part of the mountain is below the horizontal line, and therefore the perpendicular of a right-angled triangle will only represent a portion of the height. To allow for this, the following correction, which includes mean refraction and curvature, must be added to the true angle of elevation.

$$\text{Correction, in seconds of arc,} = \frac{\text{distance in geog. miles} \times 100}{4}$$

Example.—Observed with a theodolite the elevation of Kilimanjaro to be 6° 03′ from a position afterwards found to be 25 miles distant.

$$\text{Correction} = \frac{25 \times 100}{4} = 625'' = 10'\ 25''$$

Corrected elevation = 6° 03′ + 10′ 25″ = 6° 13′ 25″

Constant log. (of 6046 ft.)	. . . . . .	3·7815
Log. tangent 6° 13′ 25″	. . . . . .	9·0376
Log. 25	. . . .	1·3979
Height above observer's position = 16,480 feet	. log =	4·2170

Flashing Signals.

A flash from a small mirror is of the greatest use in surveying. Mirrors mounted so as to turn in any direction are sold by opticians under the name of heliostats, and a flash from one of two inches square may be seen fifty miles. It requires, however, an intelligent person to direct the mirror, and cannot therefore be worked by a native or untrained European. Mirrors fitted for this purpose are made of accurately parallel plate glass and a small hole is made in the amalgam and the plate protecting the back of the glass.

Planting the stand of the mirror fairly, the hole in the centre is looked through, and a piece of paper working on a stick, which must be stuck in the ground about ten paces distant, is brought into exact line with the object to which it is desired to flash and when the observer is in readiness to take the angle to the flash. The mirror is then turned about until the flash from the sun illuminates the paper, when the observer at the distant point will also see it. The flash must be kept carefully on the paper until an answering flash shows that it has been seen and observed.

Two surveyors working together in this way can obtain most accurate observations without any time being expended in erecting marks. In a persistently cloudy climate, the method is, of course, of little use.

Measurement of the Number of Cubic Feet of Water conveyed by a River in each Second.

The data required are—the area of the river-section and the average velocity of the whole of the current. All that a traveller is likely to obtain, without special equipment, is the area of the river-section and the

average velocity of the *surface* of the current, which is greater than that of its entire body, owing to frictional retardation at the bottom.

To make the necessary measurements, choose a place where the river runs steadily in a straight and deep channel, and where a boat can be had. Prepare a few floats of dry bushes with paper flags, and be assured they will act. Post an assistant on the river-bank, at a measured distance, of about half the estimated width of the river, down stream, in face of a well-marked object. Row across stream in a straight line, keeping two objects on a line in order to maintain your course. Sound at intervals from shore to shore, fixing your position on each occasion, by a sextant-angle between your starting-place and your assistant's station, and throw the floats overboard, signalling to your assistant when you do so, that he may note the interval that elapses before they severally arrive opposite to him. Take an angle from the opposite shore, to give the breadth of the river.

To make the calculation approximately, protract the section of the river on a paper ruled to scale in square feet, and count the number of squares in the area of the section. Multiply this by the number of feet between you and the assistant, and divide by the number of seconds that the floats occupied, on an average, in reaching him.

Important rivers should always be measured above and below their confluence; for it settles the question of their relative sizes, and throws great light on the rainfall over their respective basins. The sectional area at the time of highest water, as shown by marks on the banks, and the slope of the bed, ought also to be ascertained.

EXAMPLE.

Distance from Shore	Starting place.									Opposite Shore.	
Whence the boat started, measured in feet	0	90	160	240	330	420	500	600	700	780	
Depth at those distances measured in feet	0	2	3½	4	4	5½	7	6½	3½	0	
Time required for float to drift opposite to assistant, measured in seconds	—	48	50	40	33	29	27	30	50	—	Average. 38·4

Distance of assistant, in feet, 150.

By protracting the data on the first two lines, on ruled paper as described above, it will be found that the area of the section is 3260 feet, or thereabouts; this, multiplied into 150, gives 489,000 cubic feet of water as the contents of the river at any given moment between the line of soundings and the assistant. As this amount passes by in 38·4 seconds, the number of cubic feet per second is the former number divided by the latter, which gives 12,734.

It must be distinctly understood that this number is only roughly approximate, and that it is excessive. However, with the above data, an engineer would be able to make a somewhat better calculation. In the meanwhile, the traveller might consider the flow of the river in question to be between 10,000 and 13,000 feet per second.

Map Projections.

Mercator's Projection.

On a sheet of cartridge paper, 13 inches by 20, it is proposed to construct a map on Mercator's projection, on a scale of 10 miles to an inch equatorial—*i.e.* 6 inches to the degree of longitude.

$$\text{Limits of the Map} \begin{cases} \text{Lat. } 31^\circ \text{ to } 33^\circ \text{ N.} \\ \text{Long. } 34^\circ \text{ to } 36^\circ \text{ E.} \end{cases}$$

Draw a base line, find its centre, and erect a perpendicular to the top of the paper; the extremes of longitude 34° and 36° added together and divided by 2, give 35°, the central meridian, and which is represented by the perpendicular; on each side of it lay off 6 inches, and erect perpendiculars for the meridians 34 and 36; divide the base line into 10-mile divisions, and the part from 35° 50′ to 36° 00′ into miles for the latitude scale.

From Table A, take the following quantities:—

Lat. 31° to 32° =	1° 10′·4 = the distance between parallels			31° and 32°		
„ 32° to 33° =	1° 11′·1	„	„	„	32° „	33°
	2° 21′·5	„	„	„	31° „	33°

Having thus obtained the distances between the required parallels, divide the map into squares of 10 miles each way, and the map is ready for the projection of the route.

(A.)—Table to construct Maps on Mercator's Projection.

°	0 °	1 ° ′	2 ° ′	3 ° ′	4 ° ′	5 ° ′	6 ° ′	7 ° ′	8 ° ′	9 ° ′
0		1 00	1 00·1	1 00·1	1 00·1	1 00·2	1 00·3	1 00·4	1 00·5	1 00·6
10	1 00·9	1 01	1 01·2	1 01·5	1 01·7	1 02	1 02·2	1 02·6	1 02·9	1 03·3
20	1 03·6	1 04·1	1 04·5	1 04·9	1 05·5	1 05·9	1 06·5	1 07	1 07·7	1 08·2
30	1 09	1 09·6	1 10·4	1 11·1	1 12	1 12·8	1 13·7	1 14·6	1 15·7	1 16
40	1 17·6	1 19	1 20·1	1 21·4	1 22·7	1 24·2	1 25·6	1 27·1	1 28·8	1 30·6
50	1 32·4	1 34·3	1 36·4	1 38·6	1 40·8	1 43·4	1 45·9	1 49	1 51·4	1 54·8
60	1 58·3	2 01·8	2 05·8	2 09·9	2 14·5	2 19·14	2 24·7	2 30·5	2 36·8	2 43·8
70	2 51·3	2 59·8	3 09·1	3 19·6	3 31·3	3 44·6	3 59·8	4 17·1	4 37·4	5 01·1
80	5 29·5	6 03	6 46·4	7 40·3	8 51·1	10 27·7	12 47·9	16 29·6	23 4·3	39 42·2

Use of the Table.

Find in the Table the required parallel: the tens at the side, and the units at the top. At their intersection will be found, in degrees and minutes, the distance of the required parallel from the next less degree; to be measured from the scale of longitude on the map in progress.

Given the parallel of 30°—required that of 31°.

30 at the side, and 1 at the top, intersects at 1° 09′·6, the required distance of the two parallels.

Given the parallel of 31°—required that of 33°.

$$32^\circ = 1^\circ \ 10'\cdot4$$
$$33^\circ = 1^\circ \ 11'\cdot1$$

$2^\circ \ 21'\cdot5$ the distance between the 31° and 33° parallel.

(B.)—Given the Departure, to find the Difference of Longitude.

	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	.	1·0001	1·0006	1·0013	1·0026	1·0038	1·0055	1·0075	1·0098	1·0125
10	1·0154	1·0187	1·0224	1·0261	1·0306	1·0353	1·0403	1·0457	1·0514	1·0578
20	1·0642	1·0711	1·0785	1·0864	1·0946	1·1034	1·1126	1·1224	1·1326	1·1434
30	1·1547	1·1666	1·1792	1·1924	1·2062	1·2208	1·2361	1·2521	1·2690	1·2868
40	1·3054	1·3250	1·3456	1·3673	1·3902	1·4142	1·4395	1·4663	1·4945	1·5242
50	1·5557	1·5890	1·6242	1·6616	1·7013	1·7435	1·7883	1·8361	1·8871	1·9416
60	2·0000	2·0626	2·1301	2·2027	2·2812	2·3662	2·4586	2·5593	2·6695	2·7904
70	2·9238	3·0716	3·2361	3·4204	3·6280	3·8637	4·1337	4·4454	4·8097	5·2406
80	5·7587	6·3925	7·1856	8·2057	9·5664	11·475	14·334	19·108	28·653	57·307

Use of the Table.

Find in the Table the required parallel, the tens at the side, and the units at the top: at their intersection will be found a quantity which, multiplied by the departure, gives the "diff. of longitude."

The departure from the meridian on the parallel of 34° was 25 miles—required the diff. of longitude.

$25 \times 1{\cdot}2062 = 30{\cdot}155$ the diff. of longitude.

In the parallel of 60° the departure was 30 miles.

$30' \times 2 = 60$ miles, or 1 degree.

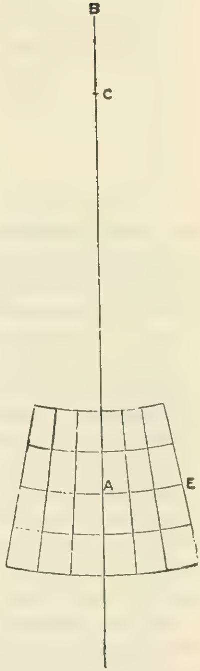
In the parallel of 35° N. the route was N. 40 W., 37 miles' distance.

Dis. Dep. Miles.

By Traverse Table, 40° course, $37 = 23{\cdot}8 \times 1{\cdot}2208 = 29{\cdot}055$ diff. of longitude.

Conical Projection.

The conical projection, or development, is carried out thus: draw a straight line, A B, to represent the central meridian of the intended map, and after having decided on the scale on which it is to be laid down, set off along this line **A** B, from the point A, scales of equal parts, for each 1° or 5°, as the size of the scale may admit. Also measure off from A towards B the distance A $C = 57 \cdot 29578 \times$ length of 1° in inches $\times$ cot. lat. of A. Then with C as a centre, and C A as a radius, describe an arc of a circle through the point A, representing the parallel of middle latitude, and divide it also into equal parts indicating 1° or 5° of longitude, each 1° of longitude being equal to 1° of lat. $\times$ cos. lat. of A; and from C draw the radiating lines, representing the meridian through the points laid off on A E, and also concentric circles through the points marked off on A B for each 1° or 5° for the parallels of latitude.



For the Rectangular Tangential Projection, see a pamphlet with Tables published by the Ordnance Survey Department, "On the construction and use of marginal sheet lines, for the uniform projection of maps in any part of the world."

SURVEYING AND ASTRONOMICAL OBSERVATIONS.

Part 3.

SURVEYING.

Mapping a Country.

The surveys that are mostly possible for travellers are route surveys, *i.e.*, laying down as much of a country as comes within the ken of a traveller on his line of march. Such surveys, if of any extent, must be assisted by astronomical observations to prevent the accumulation of errors. (*See* p. 188.)

Route surveying can be accomplished in several ways, but in any case is not an easy task for one who has no experience of ordinary surveying, as, to be successful, it requires a knowledge of how to make the most of opportunities, of which method is applicable, and generally a mastery of the various dodges by which alone an irregular survey can be made to give a result fairly approximating to the truth.

The principle underlying all surveying is to start from a base line of known length, and by means of angles or bearings to obtain rays to conspicuous objects from both ends, by the intersection of which their position can be fixed. Details are sketched in between.

The base line may be long or short, may be measured, either accurately, by means of a tape, cord, chain, etc., or by astronomical observations; or, roughly, by estimation of the distance walked in a straight line.

Tacheometer surveying is a method in which an extremely short base is used, the angle subtended by it at a point at right angles to the centre of the base being measured from the point to be fixed; in this case not at a great distance from the base.

To aid the traveller, descriptions will be given of:—

The scale of the intended survey is an important point.

This will vary much with circumstances, but the limits of scale for ordinary route surveys may be roughly stated as from half an inch to one-tenth of an inch to the geographical mile.

The geographical mile should be chosen, as it facilitates the introduction of astronomical positions from time to time.

While parts which seem to require more detail may be mapped on a larger scale, and reduced into the general map, it will ordinarily be found that a scale of a quarter of an inch will be the most convenient.

It is above all things necessary that a traveller should state distinctly how his map has been made, the bases used, the instruments employed, and generally all information that will enable the map compiler to judge of the value of the work. The compiler has in most cases to fit the new work into old, and without some information which enables him to appraise the value of both, he is at a loss what to do when discrepancies, which are unavoidable in such work, occur.

Some portions of a route map are certain to be less accurate than others, and the traveller should append remarks on this head, because the object of all travellers surveying is to add to correct mapping, and not to displace previous work by the new, without regard to the accuracy which may attach to it.

Any work incorporated from a previous map should be distinguished in some way to avoid confusion, and if such work has been altered to fit the explorer's positions, it should be stated.

Route Survey with Prismatic Compass, Boiling-point Thermometer, and Aneroid.

For the purpose of illustration, suppose the following to be an extract from a traveller's journal:—

June 1*st*.—Camp at the foot of hill A, and 2¾ miles distant from its summit, the magnetic bearing of which was 146°.

To measure the height of the hill A, above the camp, I read the aneroid and thermometer, first at camp and then on its summit, with the following results:—At camp, aneroid, 25·67 inches; temperature in

the shade, 70° Fahr.; at the summit of the hill, aneroid, 24·25 inches; temperature in the shade, 65° Fahr. At the summit of hill A, I took the following bearings, and a rough sketch of the country to the north, marking all prominent objects with a letter corresponding to the letter given to the bearing.

Bearings taken at A: G 351° 30′; F 340°; E 326°; D 308°; C 300°; B 283°. All bearings magnetic.

June 2nd, 8 A.M.—Aneroid, 25·7 inches; temperature in shade 78° Fahr. Struck camp, and travelled in a direct line towards hill marked E in the sketch, and at a distance, which I estimated to be fifteen geographical miles, we arrived at the right bank of a river, where we camped for the night. The country over which we have passed this day is destitute of trees, sandy, with patches of grass here and there, and gradually slopes downwards from our last camp to our present position. 6 P.M.: aneroid, 25·98 inches; temperature in the shade, 68° Fahr.; took the following bearings:—

Bearings taken at camp, 2, by river: D 270°; B 204°; A 146°; G 100°; F 8°. All bearings magnetic.

June 3rd, 8 A.M.—Aneroid, 26·05 inches; temperature in shade, 78° Fahr. Struck camp, and forded the river, which, after winding in an easterly direction from the hill, marked D in the sketch, to a point one and a half miles N.E. by E. of the ford, takes a bend to the S.E., passing to the west of the hill marked G on the sketch. At a distance of one mile below the ford, a large stream from the north flows into the river. Continued to travel in the direction of E, and at noon found that we had arrived at a point where C and F and our position were in one line of bearing—81° and 261° magnetic. During our halt, boiled a thermometer and read the aneroid, with the following results: water boiled at 204·3°; aneroid, 25·62 inches; temperature in the shade, 71° Fahr. 3 P.M. Resumed our journey, and at 6·30 P.M. reached the summit of the hill E, where we camped; estimated distance travelled, nineteen geographical miles. Aneroid, 24·60 inches; water boiled at 202·3°; temperature in the shade, 64° Fahr. Since leaving camp this morning, the country through which we passed was covered with vegetation, and we had the large stream to the right of us throughout the day. From this hill, E, we can see that the river we forded this morning takes its rise in the range of hills to the west of our present position, and flows with a wind-

ing course through the valley at the foot of the hill D, and so past our last camping-ground.

Bearings taken at E: C 236° 30′, and southern end of summit of same range, H 215°; D 174°; B 168°; A 146°; G 133°; F 118° 30′. All bearings magnetic.

June 4th, 8 A.M.—Aneroid, 24·65 inches; temperature in shade, 66° Fahr. Set out in a N.W. direction, and having no prominent object in view on the line of march, I noticed the direction in which my shadow was cast, and by this means, allowing for the sun's apparent motion, I avoided making any general deviation from the direction in which I wished to travel. Arriving at a small lake, we camped, having come an estimated distance of twelve geographical miles. Fixed the position of the lake by bearings of C and E.* Aneroid, 25·50 inches; temperature in shade, 70° Fahr.

Bearings taken at camp, near lake: C 195° 30′; H 185° 34′; E 113° 30′. All bearings magnetic.

To Plot the Bearings:—This can be done either on the true or magnetic meridian. The bearings being magnetic, it saves much trouble, and also chances of errors, to plot them from the magnetic meridian.

Through the station A draw with a pencil a line to represent the magnetic meridian in a direction convenient for the route. Place the protractor with its centre mark on A, and the 360° on the magnetic line, and set off the bearings observed.

The second camp being in the direction of hill E, measure 15 miles, on the scale adopted, on the line drawn toward E, which will give the position of Camp 2.

From this position lay off the bearings obtained, in a similar manner, having first drawn a magnetic meridian through it parallel to the first. The intersection of two lines of bearings of any one point, as taken from two different stations, will fix the position of that point with reference to the stations. If the true meridian is used, the procedure is the same, but each bearing must be corrected for the variation before laying-off, which can be approximately ascertained from the variation map (p. 158).

* Take 180° from C for its opposite bearing. Add 180° to E for its opposite bearing.

The line drawn through A will then represent the true meridian. In both cases it should be stated on the map whether the meridian is true or magnetic.

Each station where bearings are taken must be plotted in a similar manner to Camp 2, that is, by bearing from the last station, and by estimated distance. Having by means of the first two stations fixed hills off the line of march, bearings of these will assist to obtain the position of the third, and so on. When no object can be seen to march for, the direction must be obtained by compass bearing of the line of march obtained from time to time.

The aneroid readings, and the boiling-point, furnish us with the means of ascertaining the difference in height of two stations, which may be computed by the tables (see pp. 313 to 320), or, where the height is not considerable, by a simple arithmetical process as follows:—

Take the sum and difference of the aneroid readings, at the upper and lower station, get the mean of the temperature in the shade at the two stations. Then, sum of readings: difference of readings: : 55,000: the difference in height. Increase the result thus found by $\frac{1}{435}$ of itself for every degree that the mean temperature in the shade at the two stations exceeds 55°; subtract the like amount if it is below 55°. The aneroid readings, in the example, computed by the tables and this formula, will show a fairly close agreement.

	Approximate Method. Feet.	By Tables. Feet.
A, above Camp 1	1608·5	1603·8
1st Camp above 2nd Camp	310	308·8
Foot of Range above 2nd Camp	477·2	475·9
Height of Range E...	1148·2	1145·0
,, by Boiling point ..	.. ..	1155·3
E above Lake	959·2	956·5

For plotting the work in the field, a scale of one inch to the geographical mile will exhibit all the main features of a country traversed in a day's journey. Special plans must be drawn on a scale suited to the area they are intended to represent; but whatever scale is chosen for the field work, it should be large enough to admit of considerable reduction in the fair plan, as by this process all errors are diminished. The projection of maps

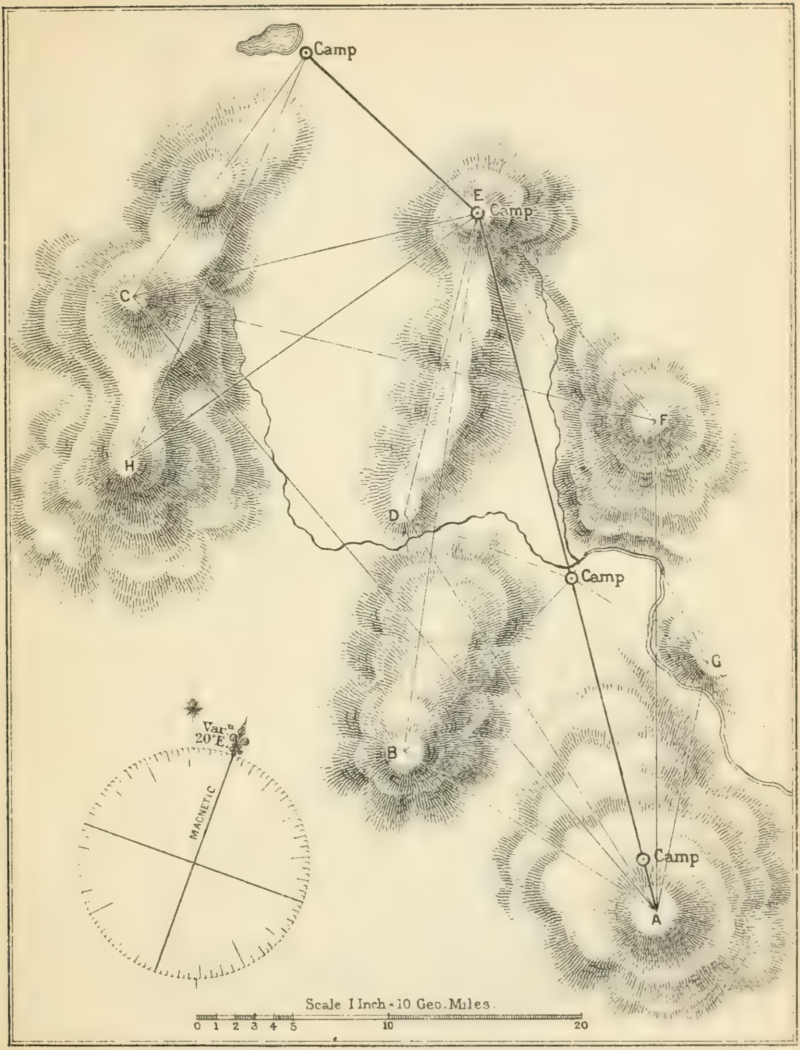
is purposely omitted here, as it is dealt with separately (see p. 148); it will, however, be of great assistance to the traveller if he provides himself with a blank map, on the scale of ten geographical miles to an inch, of sufficient range in latitude and longitude to include the country he intends to explore. He should also procure some paper ruled with dark lines into inch squares, and then again subdivided into five smaller squares; this will be useful to him for plotting his work in the field, and should be made up in the form of an ordinary sketching-block. Should the latitude and longitude of the point of departure be known, the latitude and longitude of any place on his route can be approximately determined by working the traverse as directed in articles 286 and 324 of Raper, or pages 115–120 of Norie. It must not, however, be supposed that an accurate survey of a large tract of country can be made with the aneroid, prismatic compass, and boiling-point thermometer; the most that a traveller could expect to do with the aid of these instruments would be to make a rough sketch of the country through which he passed. But instances are not wanting where travellers, by a judicious use of these simple instruments, have added very considerably to our geographical knowledge. The map of Schweinfurth's journey to the Welle is an example of what can be done with the material furnished by such observations.

The weak points in this method of surveying are, the errors caused by false estimates of the distance travelled, and those arising from the effects of local attraction on the compass. Knowing these sources of error, every care should be taken to guard against them. With regard to distance, the only safe way of estimating it is, by carefully noting the time occupied in passing from one place to another. In almost all countries bodies of men have a nearly uniform rate of progression, and by taking an early opportunity of noting this rate, the distance traversed in a known period of time can be fairly estimated. Schweinfurth, before setting out on his great journey to the Welle, carefully noted the time which it took him to pass over a known distance at a regular pace, to which he had trained himself; and truly wonderful results have been attained by native surveyors in India by following the same plan. The only precautions that can be taken against the effects of local attraction on the compass are, to be careful when taking a bearing to put all arms, such as rifles, at some distance from the compass; as a general rule,

where possible, to avoid all rocks; and to take bearings both forward and backward on the route travelled, taking their mean as the magnetic direction of the route. In a country thickly covered with forest it is most difficult to distinguish landmarks. The traveller may, however, sometimes leave a mark recognisable at some miles distance by giving a little consideration to it, and knowing the direction in which he is proceeding.

Enter every observation and change made in the general direction travelled, with the date and time, in the journal; as without attention to this, much valuable information may be lost. When preparing MS. to be sent home for publication, write each of the native names, *at least once*, in printing character. Numerous errors and great loss of time frequently result from the attempt to decipher proper names written by travellers in their ordinary handwriting only.

The bearings given in the journal have been laid down on the annexed map, corrected for 20° easterly variation, and will serve to illustrate the manner in which this portion of the work is done.



Published by the Royal Geographical Society in "Hints to Travellers", 1893.

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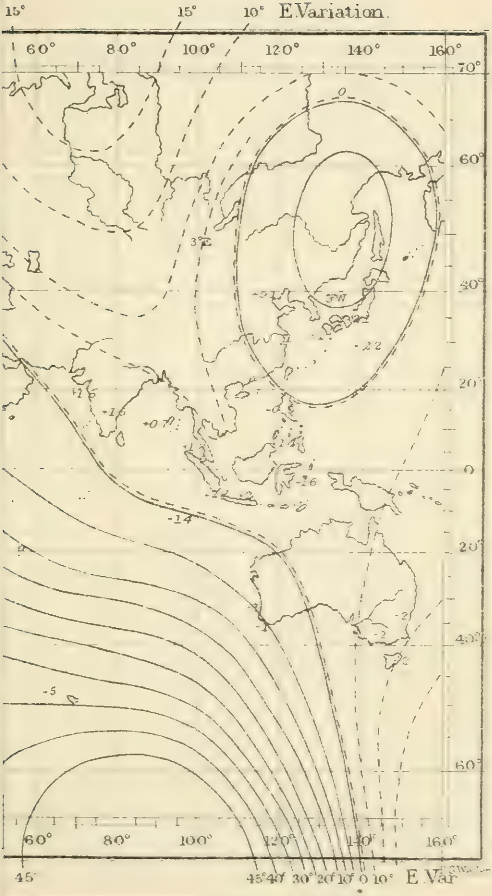
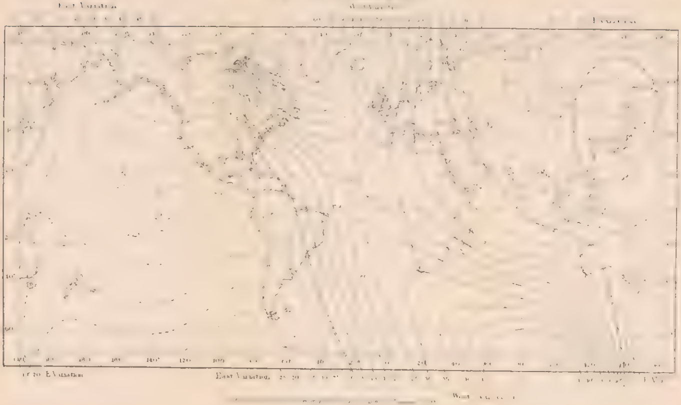


Variation.

LINES OF EQUAL MAGNETIC VARIATION_1893



Hints on Use of Sextant in Surveying.

To measure the Angular Distance between two Objects.

When the horizontal angles between terrestrial objects have to be taken with the sextant, the index is set to zero (0°), and the instrument must be held in the right hand in such a manner that its plane is parallel to an imaginary line joining the two objects; put back all the dark shades, and, looking through the telescope collar and the horizon glass at the *right* hand object, unclamp the index and move it slowly forward until the reflected image in the mirror of the horizon glass coincides with the other object seen directly; clamp the index and make the coincidence perfect with the tangent screw, then read the angle. Make it a rule to commence taking the angles from the object farthest to the right, then from the next farthest, and so on, always working from right to left. By so doing mistakes will often be prevented in plotting the work, and you will be able to recognise the objects from which angles have been measured in your rough sketch. Avoid very large or very small angles, as they may cause considerable errors in the positions assigned. Should it be required to measure the horizontal angle between two objects, one of which is at a considerable elevation above the other, as a tree on a plain and a mark on the top of a hill, it will be necessary to select some object immediately below the mark on the hill, and as nearly as possible on the same level as the tree, and measure the angle subtended by them. If no object in a suitable position can be seen, select some point about 90° or 100° from one of the objects, and observe the angles between each object and that point; the difference between these two angles will be the horizontal angle, nearly. Should the angle be too large to be taken in one measurement, the object to the right must be brought by reflection to some well-defined mark, and the reading taken; the angle must then be measured between the mark and the other object; the sum of these readings, after the index error for each measurement has been applied, will be the angle required. Though the angles measured with the sextant are seldom, strictly speaking, the true horizontal angles, yet the errors arising from their obliquity are extremely small, if they have been well chosen, and indeed would be scarcely discernible, in work

plotted with the ordinary protractor, which is only divided to 30′. A reference to the following diagrams will, it is hoped, make the previous remarks on this subject more clearly understood.

In Fig. 1 let A B be two objects, O the place of the observer; then the objects would appear in the horizon glass as shown in Fig. 2, when the angle was taken; A being seen in the mirror, B by direct vision through the unsilvered part. If the angle A O B had to be taken by two measurements, A O C would have to be taken first, and then the angle C O B; the sum of these two angles, which is the angle A O B, is the horizontal angle between A and B′, very nearly, because B is directly beneath B′, and is more nearly in the same horizontal plane as A. When a box sextant is used the reflected image is seen above the object by direct vision. In Fig. 3, if the horizontal angle between A and B had to be measured, select a point such as C, more than 90° from A, and at O, the place of the observer, take the angles A O C and B O C; the difference of these two angles will be more nearly the horizontal angle between A B at O, than the angle A O B.

TABLE FOR ASCERTAINING HEIGHTS AND DISTANCES BY THE SEXTANT.

Mul.	Angle.	Angle.	Div.
	° ′	° ′	
1	45 00	45 00	1
2	63 26	26 34	2
3	71 34	18 26	3
4	75 58	24 2	4
5	78 41	11 19	5
6	80 32	9 28	6
8	82 52	7 08	8
10	84 17	5 43	10

The sextant being set to any angle contained in the Table, any height or distance of accessible or inaccessible objects may be obtained in a very simple and expeditious manner. Make a mark on the object, if accessible, to the height of the eye; set the index to any angle from the Table, and advance or go backwards from the object, until, by reflection, the top of the object is brought by the mirrors to coincide with the mark first made. If the angle be greater than 45°, multiply the distance to the object by the number in the next column to the angle in the Table; if the angle be

Fig. 1.

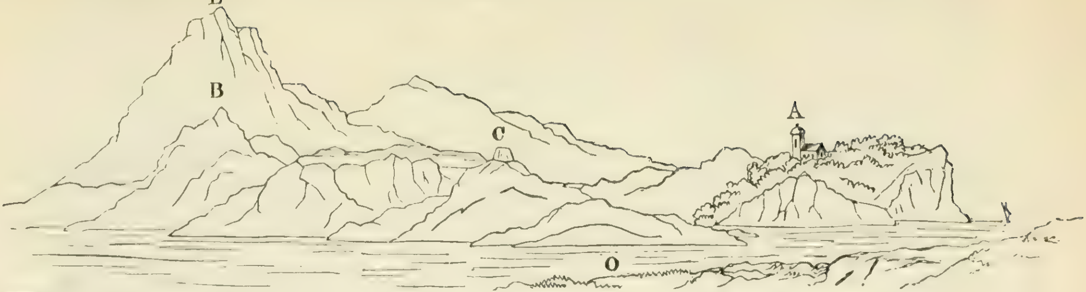


Fig. 2.

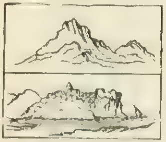
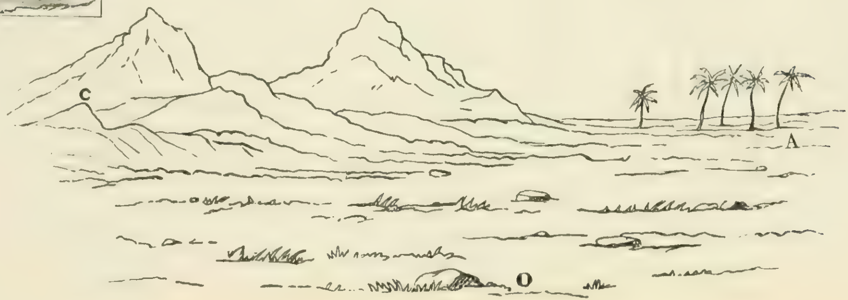


Fig. 3.



less than 45°, divide, and the result will be the height of the object from the mark; to which add the height of the eye.

If the object is inaccessible, set the index to the greatest angle in the Table that the least distance from the object will admit of; move backwards and forwards until the top of the object is reflected level with the eye; at this place set up a staff equal to the height of the eye. Then set the index to any of the lesser angles; go back in a line with the object, until the top is made to appear on the level with the top of the staff; fix here another mark; measure the distance between the two marks set up; divide this by the difference of the numbers corresponding to the angles made use of, and the quotient will be the height of the object from the top of the staff; to which add the height of the eye.

If the index is set at 45°, the distance is equal to the height, minus the height of the eye.

At a given point to mark off a line perpendicular to any given direction.—If this direction is not sufficiently distinguished by some natural object, such as a tree, mark it by a flag set up as far off as convenient; then, standing at the given point, with the sextant set to 90°, make a man, bearing a flag, stand in a line estimated as the perpendicular. Motion him right or left until his flag can be seen, by reflection, to coincide with the other. There let him plant his flag, so marking the direction of the perpendicular.

Of course any other direction can be marked in the same way, setting off the required angle on the sextant, instead of the 90°.

Surveys with Sextant and Prismatic Compass.*

By Col. Sir C. W. Wilson, R.E., K.C.B.

A traveller who intends to devote a portion of his time to the survey of the country he is about to visit, should consider before leaving home what he is going to do, and how he will do it. The character of the proposed survey, the projection to which it is to be referred, the scale or scales to be adopted, the instruments to be used, should be carefully thought

* It will be understood, that if a small theodolite can be carried, the work of surveying will be greatly facilitated.

over before commencing work, and there should be no hesitation when once upon the ground. A decision on these points depends on various considerations—such as the time and means at the disposal of the traveller, the object in view, the nature and geographical position of the country, &c.; and the following notes are confined to a few hints which may be useful in the field.

Projection.—When the extent of country to be laid down is small, it may be treated as a plane-surface; but when it is considerable, allowance must be made for curvature, and some projection of the sphere, or a portion of the sphere, adopted. The projection should be selected with reference to the latitude and local peculiarities of the country to be surveyed; the sheet should be prepared before leaving home by a competent draughtsman, and two or more copies of each taken, packed in a round tin plan-case. It may happen, however, that a projection has to be made in the field, and a few notes are given on the construction of Mercator's, the Conical, and the Rectangular Tangential Projections (*see* p. 148). In *Mercator's Projection*, the true proportions are preserved between the meridians and the parallels, and the figures of the objects delineated are in every part correct; but the exaggeration at a distance from the Equator is so great that, beyond 50° or 60°, a circular or polar projection is preferable. The advantage of Mercator's projection is, that the bearing and distance of one place from another, as measured on the map, is the same as on the globe itself; the traveller can thus lay down his route upon it with great readiness. The *Conical Projection* is well adapted for the representation of small portions of the sphere; but if the map is extended much above or below the middle latitude, the distant parts will be greatly distorted. The *Rectangular Tangential Projection* is well suited for maps on a scale of 10 miles to an inch; and the tables published by the late Sir Henry James provide the means of readily constructing the sheets required.

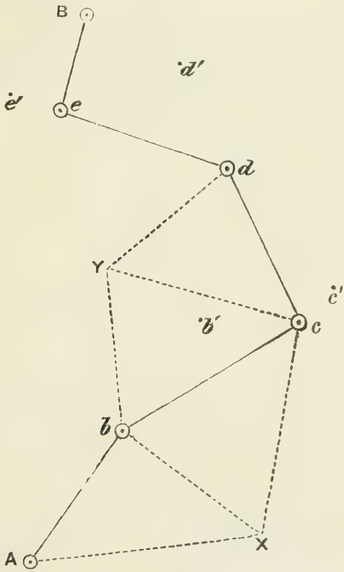
Scale.—For the fair plan, a scale of 10 miles to an inch is recommended, for the field sketch or outdoor-work, a scale of 2 miles to the inch; or, if much detail is required, of 1 mile to the inch. The scale of 2 miles to the inch has this advantage—that the ordinary sketching-card $12'' \times 15''$ will contain sufficient ground—24 miles × 30 miles—for the day's work and most of the points to which bearings are taken.

The classes of *Survey* to which attention may be directed are—1. A

simple route-survey; 2. A district-survey; 3. A special survey of a small tract of country; and 4. A survey of a plot of ground containing ruins, &c. The only instruments supposed to be available are—sextant, watch or chronometer, prismatic compass, measuring tape, aneroid, &c.

1. *Route Survey.*—Arrived on the ground, the traveller must first fix, with as much accuracy as possible, the position of some point on the earth's surface to which his work may be referred. If he starts from the coast-line, the position of some well-defined point can generally be obtained from the Admiralty Charts, but if no such resource is available, the position of his initial point must be determined by astronomical observations. The latitude can be obtained by a good observer with a 6-inch sextant to about 100 yards on the earth's surface; but the longitude is seldom found by lunar distances to within ten minutes (10 miles on the Equator). The position of the initial point, A, having been determined, work commences. The true bearing of some well-defined distant peak, or other landmark, is obtained, and this having been made "zero," a round of angles is taken with the sextant to conspicuous objects, some of which should be in the direction of the proposed line of march, and, if possible, near the first halting-place. Several observations of the zero-point are made with the compass, the needle being deflected each time, to obtain the variation, and the aneroid read for altitude. All angles should be booked at once in ink, and the names of the observed objects carefully noted; a rough outline-sketch of the peaks or other landmarks will be found useful in identifying points as the work proceeds. The initial point, A, is pricked off on the sketching-card in a suitable position for laying down the day's march, and surrounded by a circle ⊙; the observed angles are plotted; and a magnetic meridian is drawn; all is then ready for plotting the route. The compass is set up at A, and the sights of the instrument are directed on some object, b', in the direction of the line of march; the bearing of b' is read off and plotted from A on the field-sheet by means of the protractor; bearings are then taken to conspicuous objects such as X, which appear to lie near the line of march, and these are likewise plotted. The march now commences in the direction of A b', and is continued to the point b, where the route is found to turn to the right; the distance A b, measured during the march, is laid down upon the field-sheet, and the point b, surrounded by a circle ⊙; the compass is then set up at b, and the bearing of an object, c', in the direction of the new line of

march, read off and plotted from b on the field-sheet; bearings are also taken to objects, such as X, Y, on either side of the route, and plotted; the point X having also been observed from A, is now fixed. The march is again taken up in the direction $b\ c'$ until a point c is reached, at which the road bends to the left, the distance $b\ c$ laid down, and so on until camp B is reached. At B, observations should be made in the evening for time and latitude; and in the morning, observations similar to those which



have been made at A. Should the camp be near one of the points observed to from A, the distance and true bearing of such point from B should be determined, with a view of fixing its position. At certain camps the longitude should be found by lunar distances, or other methods, to serve as a check on the traverse-survey. Distances on the line of march may be measured by counting or timing the paces of a man, or by counting or timing the paces of a horse, mule, camel, &c., whose length of step is

known. Time-measurement will be found most convenient, and, with care, will give very good results. Compass-bearings need only be taken at every second station on the line of march. Objects on either hand should, where possible, be fixed by three bearings. It is not desirable to take compass-bearings to points more than 6 or 7 miles distant, as the prismatic compass can seldom be depended upon to within one degree, and an error of this amount in 6 or 7 miles would give an error of ·05 inch on a scale of 2 miles to the inch. If the route runs near a peak, of which the true bearing has been determined from A, it should be ascended, and a round of angles taken with the sextant, making A the zero-point. When there is a mid-day halt, the meridian altitude of the sun should be observed. If a field-sketch cannot be kept up, the route should be entered in a field-book, and afterwards plotted, before details are forgotten. A book—with every alternate page ruled into squares by strong lines, and subdivided by finer lines, the smaller squares representing five minute intervals of time, the larger ones one hour—will be found of great use in making a rough sketch of the route; or a modification of the form used in booking a traverse-survey may be adopted. In all cases the bearings, distances, &c., should be clearly written in the book.

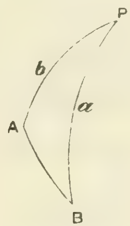
In this field-sketch the ground has been treated as a plane surface, and as soon as convenient the work should be transferred to the projection on the fair plan. In doing this it becomes necessary to calculate the latitudes and longitudes of the camps, and other points, from the material provided by the survey; when this has been done, the fixed points are laid down in their true positions on the map, and the detail reduced to the proper scale.

2. *District Survey.*—The basis of any survey of an extensive district should be a system of triangulation, and the first step is the measurement of a base line. With no instruments except a sextant, tape and prismatic compass, the best plan is to measure an astronomical base, and thence extend the triangulation as far as may be necessary. Two suitable points, A and B, lying nearly north and south of each other, are selected as the ends of the proposed base; the position of A on the earth's surface is determined at the point itself, the true bearing of B from A is obtained, and B having been made zero, a round of angles is taken with the sextant to conspicuous points; camp is then moved to the vicinity of B, and observations for latitude made at that point; the true bearing of A from B

is then obtained, and a round of angles taken to the points previously observed to from A. The length of the base A B can then be computed and the position of several of the points observed to from A and B determined. The fixed points are next laid down on the field-sheet, and the detail filled in with the prismatic compass. In this way the triangulation may be extended over the district to be surveyed, care being taken to check the work occasionally by observations for latitude at selected points.

The following notes and problems* will be found useful in constructing the map:—

Problem I.—Let A and B be two stations visible from one another, $AP = b$, $BP = a$, their observed co-latitudes; the angles A and B their



reciprocal true azimuths; and A P B, or P, the required angular difference of longitude. Then by spherical trigonometry—

$$\text{Cot. } \tfrac{1}{2}\, P = \frac{\cos.\ \frac{1}{2}\,(a+b)}{\cos.\ \frac{1}{2}\,(a-b)} \tan.\ \tfrac{1}{2}\,(A+B)$$

which determines P.

Problem II.—The latitude and longitude of any point being known, that of any other point within a short distance can be determined by plane trigonometry. Suppose the latitude and longitude of the camp at A to be known, whence that of a neighbouring peak or land-mark, C, is to be determined; the distance A C must be measured, and the azimuth N C A observed, then the difference of longitude AB is the sine of A C B to radius

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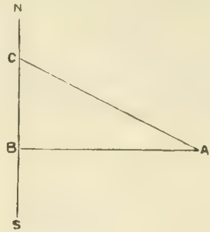
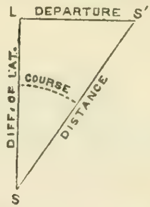
* Problems II.–V. are taken from Frome's 'Outline of a Trigonometrical Survey,' revised by Major-General Sir C. Warren, R.E.

AC, and the difference of latitude B C is the co-sine to the same angle and radius.

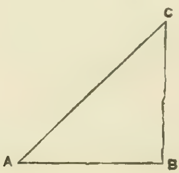


Problem III.—The distance between two places is generally resolved by plane trigonometry, the difference of latitude S L, and the azimuth, S′S L, called the *course*, forming a right-angled triangle, in which S S′, the *distance*, is determined: the other side L S′, termed *departure*, being the sum of all the meridional distances passed over.



Problem IV.—Given the distance travelled on a given parallel of latitude to find the difference of longitude.

Again, in the triangle A B C, let A B represent the distance or departure,

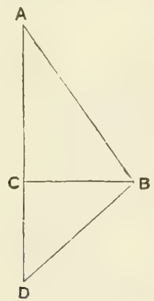


and the angles B A C be equal to the latitude, then A C, the hypothenuse will be equal to the difference in the longitude.

Problem V.—Given the departure to find the difference of longitude.

Also, if D B represent the distance, and C D the difference of latitude, then B C D will be a right angle, and B C the departure, nearly equal to the meridian distance in the middle latitude. If, then, in the triangle A B C the angle A B C be measured by that middle latitude, A B, the hypothenuse will be nearly equal to the difference of longitude between D and B.

For the variation of the compass, it is convenient to take a bearing of the sun at sunset or sunrise; or, if this cannot be done, an azimuth of the sun at any time three hours before or after noon will answer equally

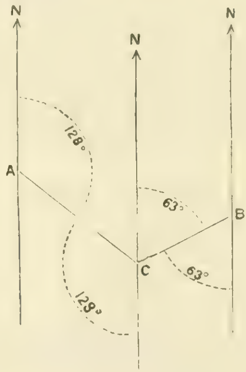


well. From the angular distance between the sun, when its own diameter is above the horizon, and any well-defined peak, measured with the sextant the true bearing can be obtained.

To find the sun's true amplitude for any day :—to the log-secant of the latitude, rejecting the index, add the log-sine of the sun's declination corrected for the time and place of observation. Their sum will be the log-sine of the true amplitude. If the true and magnetic amplitudes be both north or both south, their difference is the variation; but if one be north and the other south, their sum is the variation; and to know whether it be easterly or westerly, suppose the observer looking towards that point of the compass representing the magnetic amplitude; then, if the true amplitude be to the right hand of the magnetic, the variation is east, but if to the left hand, it is west.

In filling in a survey, the observer can fix his position, C, by observing two fixed points, A and B, and plotting from those points the opposite bearings to those observed; their intersection fixes the point required. The nearer the two bearings meet at a right angle the more correct will the point be determined, and, if a third fixed point is visible, a bearing to it will act as a check on the other.

A third and accurate method of fixing the position is by the angles subtended between three known objects. The instrument called the station-pointer is generally used for this purpose; but the position may also be found with a pair of compasses and protractor, or, more simply,

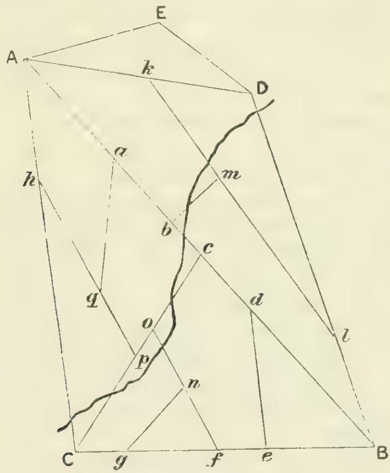


as follows, by means of a protractor and a sheet of tracing paper. Draw a line through the centre of the paper; place the protractor on it near to the bottom of the sheet; lay off the right-hand angle to the right, and the left-hand angle to the left of the centre-line; rule pencil-lines, radiating from the point over which the centre of the protractor has been placed, to the points that have been laid off; then place the paper on the plan or map, and move it about until the three lines coincide with the objects taken; prick through the point that lay beneath the centre of the protractor, and the observer's position is transferred to the plan. When possible, the centre object should be the nearest.

Any object whose true bearing is east or west must be in the same latitude as the place of the observer.

Any object whose true bearing is north or south must be in the same longitude as the observer.

3. *Special survey of a small tract of country,* with compass and tape only.—First walk over the ground and examine it, with a view to the selection of prominent points for stations, and of a level space for the



A B —Main line.
A B C } —Principal triangles.
A B D }
C c—Tie line.

measurement of a base. Having fixed upon a base, A B, set the compass up at A, and take a round of bearings to B and other selected stations, C, D, E, &c.; then mark A on the field-sheet, in such a position as will enable the whole sketch to go on the sheet, and protract the several bearings from it. Mark A on the ground with a pile of stones or staff, measure the base A B with the tape or by pacing, lay the distance down on the field-sheet to the adopted scale, set the compass up at B, and take

a round of bearings to A, C, D, E, &c. These bearings are now plotted, and their intersections with the bearings from A fix C, D, E, &c.; in this manner a rough triangulation is established, and a number of points fixed, by the aid of which the detail can be filled in.

The paper, or field-sheet, for sketching with a prismatic compass, should have parallel lines at unequal distances ruled upon it, to be considered as east and west lines.

4. *Survey of a plot of ground containing ruins, &c.*—In making a survey with a tape alone, we are confined to the simplest geometrical figure—the triangle, as it is the only one of which the form cannot be altered if the sides remain constant. In carrying out such a survey, divide the surface into a series of imaginary triangles, as large as the nature of the ground will admit of, and attend to the following rules:—

1. Do not be in a hurry to commence work, but walk over the ground, and make a rough eye-sketch of it on paper.

2. Select two points, as far apart as possible, visible from each other, and commanding a good view; let the points be near the boundaries of the ground, and so situated that the line joining them forms a sort of diagonal; this becomes the *main* line.

3. Select a point on each side of the main line, near the boundary of the work, to which lines can be measured from each end of it, thus giving two large triangles; then measure a check, or *tie* line, from one of the vertices to a point at, or near the middle of the opposite side.

4. On the sides of these triangles, erect smaller ones to embrace all the ground to be surveyed.

5. Measure lines from any station laid down, or from any part of a line connecting two of them in directions most convenient for obtaining the detail, taking offsets to such objects as present themselves.

The interiors of large buildings should be measured in a somewhat similar way, by dividing them into imaginary triangles, and measuring tie lines.

The great principle in all surveys is to work from a whole to the parts; errors are thus subdivided and time and labour economised.

The following symbols are recommended for adoption :—

∠'s signifies angles.
△ a station in the triangulation.
⊖ „ fixed by latitude.
⦶ „ „ longitude.
⊕ „ „ lat. and long.
⌖ „ „ true bearing.
>| „ „ right tangent.
|< „ „ left „

Surveying with the Plane Table.

(*For a description of this instrument, see p.* 124.)

The first thing for the traveller to decide on, in commencing a survey, is the direction and extent of his base; and, as no special instructions can be given for a base suitable for all surveys, it is a matter in which he must exercise his own discretion, bearing in mind the following points: that the length of the base line should not be out of proportion to the distance of the points to be fixed, and that the first points to be fixed must be visible from both ends of the base line. The length of the base should be accurately measured, or determined by observation. The direction of the base line must depend on the positions of the points to be fixed, as, when the angles subtended are either too obtuse or too acute, a small error in the alignment will produce a large one in the survey.

Having decided on a base line, call it A B (Fig. 1, p. 174), set up the plane table over A, and arrange the board so that the direction of *a b* will suit the position of the first portion of the survey. Level it by moving the legs of the tripod, and using the circular level on the ruler. Clamp the table, and mark a point on the paper in any convenient position, to represent A on the ground, call this *a*. Stick a pin in at *a*, and, placing the fiducial edge of the ruler against this pin, turn the ruler about until the other end of the base, B, can be seen through the slit on one of the alidade sights, on the wire of the other sight, then draw a line along the fiducial edge

from *a* towards *b*, and take the distance from A to B with the compasses from the scale on which it has been decided to construct the map; set it off on the line just drawn, and mark it *b*; then *a b* on the board will represent the base line A B on the ground. Now set the sights in turn on the other points it is desired to fix, and, keeping the fiducial edge of the ruler against the pin at *a*, draw faint lines to each of them. To prevent mistakes, these lines, called "rays," should be marked with reference numbers indicating the object to which they are drawn, or the name of each object should be written against the line drawn to it. Having done this, place the compass on the table, and turn it about until the needle points exactly to the centre mark in the compass box, which will be

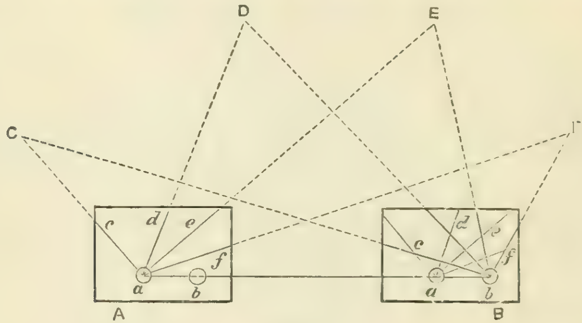


FIG. 1.

magnetic north, then draw a dark line upon the paper, along the edge of the compass box, which can be afterwards used for orienting the table as explained (page 179).

Having drawn all the rays at station A, remove the table to station B, set it up and level it in the manner before described; then stick a pin at *b*, place the fiducial edge of the ruler against it, and against *a*. Unclamp the table, and turn it about until the sights are directed on A, then clamp the table, and it will be in a position to continue the work. The process of pivoting the ruler against the pin, and directing the sights on the objects to be fixed, is to be repeated precisely in the same manner as at station A, and the points where the rays drawn from *b* intersect the

rays drawn from a will be the position of each object on the map. Fig. 1, p. 174, illustrates the manner in which the work is done.

To continue the survey by obtaining fresh rays to objects from another station.—First orient the table correctly, and find the position of that station on the board.

By *orienting* is meant placing the table in such a position that the north and south line on it shall correspond with the magnetic north and south; or, what is the same thing, so that the line drawn between any two stations on the board shall be parallel to the line between the stations on the ground.

The position on the board of the station at which the board is set up can be found, and the board oriented in a variety of ways.

(1.) *When the station has been fixed by two rays from the ends of the base or from other stations,* all that has to be done is to place a pin in the board at the station mark, lay the fiducial edge of the ruler against it and against the mark on the board indicating the most distant station from which a ray has been drawn, turn the board until the sights are in a line with A, and clamp the board which is then oriented.

(2.) *To find the position when only one ray has been drawn to the station:*—Set up the table over the station to be fixed, say D (Fig. 1, p. 174) and place the fiducial edge of the ruler along the ray that has been drawn, say a, d, turn the table until the sights align on A, clamp the table which will then be oriented. Place a pin in at b on the table and turn the ruler about until it is aligned on B, and draw a line which will intersect the line already drawn at d on the table, the position required.

Repeating the last operation with other fixed stations will, if the lines intersect, give certainty to the new position.

It may be mentioned that it is always preferable to choose a station which has one ray already drawn to it, to fixing by any of the following methods.

(3.) *To find the position when no ray has been drawn to it, but with the fixed points on the board,* the following methods may be employed.

With three visible stations, A B C (Fig. 2), represented on the table by a b c, the table can be oriented, and the position of an unknown point x found.

First Method.—Fix a pin in the point b on the plane table, and placing the ruler against it and the point a, with the object and sight

towards a, turn the table about until the point A is intersected; then, clamping the table in this position, turn the ruler and intersect the point C, with the edge of the ruler still against the pin at b, and draw the line $b\ m$:—Now remove the pin to the point a, and unclamp the table, place the ruler against the pin at a, and the point b, and turn about the table until the point B is intersected (*vide* 2); clamp the table again, and, having intersected the point C as before, draw the line $a\ n$. Through the intersection p of the lines $a\ n$ and $b\ m$, draw

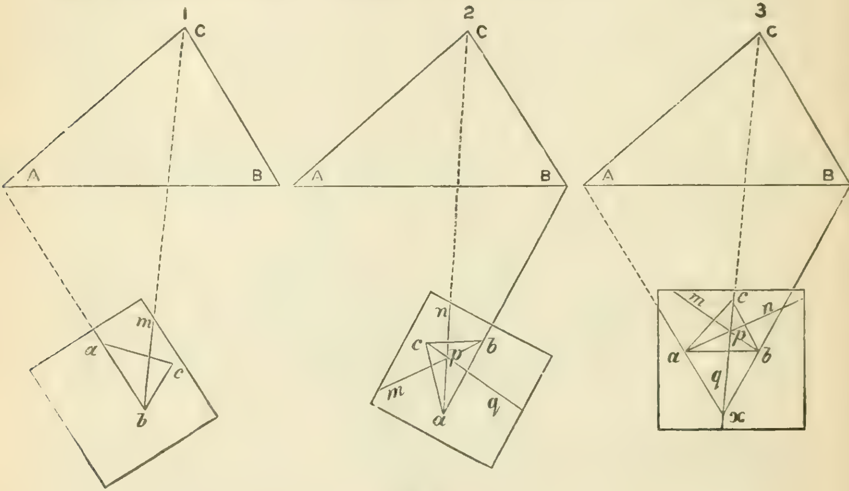


FIG. 2.

the line $c\ p\ q$ passing through the point c, and, placing the edge of the ruler against this line, unclamp the table once more, and turn it about until the point C is intersected (*vide* 3); now clamp the table, and it will be oriented, and the unknown point x will be situated on the line $c\ p\ q$; to find this point it is merely necessary to place the pin at a, and intersect the point A; draw the line A $a\ x$. The accuracy of the operation is tested by intersecting the other point B in the same

manner, and drawing the line B b x, which should intersect the line A a x on the line c p q, thus giving the position of x on this line.

When the point c, with regard to the point x, is situated on the other side of the line A B or below it, the lines a n and b m will intersect on the opposite side of the line a b, to that on which c is, and, if the point x be situated within the triangle A B C, these lines (a n and b m) will diverge instead of converge, in which case they must be prolonged in the opposite

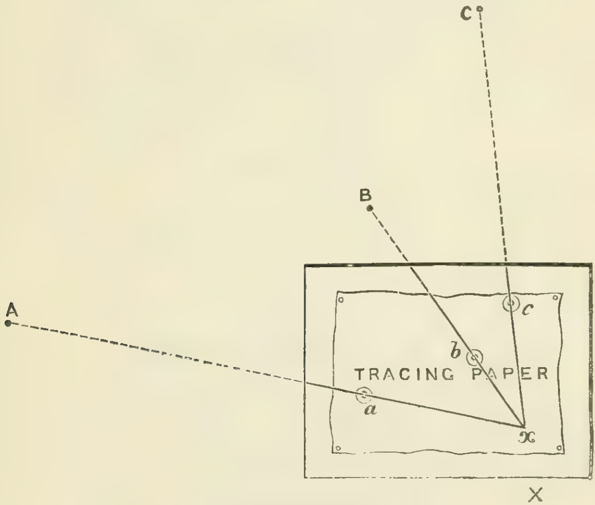


FIG. 3.—(*Good.*)

direction until they intersect for the point p. The accuracy of this result depends upon the length of the line c p.

Second Method.—Fasten a piece of tracing paper over the survey with drawing-pins, stick a pin in at any point x on the table (Fig. 3), place the fiducial edge of the ruler against it and point the sights in turn on the stations A B C, on the ground, represented by a b c on the plan, drawing lines towards you on each occasion until they meet at x. Now take out the pins that fasten the tracing paper to the board, and shift

it about until each of the lines passes through its corresponding station, as shown on Fig. 3. Prick through x, which will be your position on the plan.

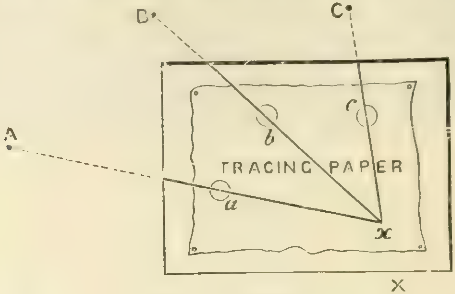


FIG. 4.—(*Bad.*)

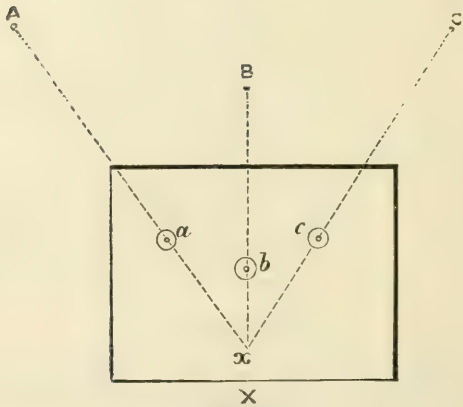


FIG. 5.

In using this method, however, care must be taken to select objects placed so that the centre one shall be the nearer, or the position found may be considerably in error.

For example, a position obtained by this method from objects as in

Fig. 4 would be of little value, as x on the tracing paper could be moved considerably to the right and left without displacing the several lines on the tracing paper off the stations a b c on the board.

For further information on this subject, see a pamphlet, 'On the Station Pointer,' published by the Admiralty, and sold by J. D. Potter, 31, Poultry, E.C.

(4.) *Orienting and fixing by the Compass.*—Set up the table over the station X to be fixed, represented by x on the board (Fig. 5, p. 178); place the edge of the compass-box against a line drawn on the paper where the needle pointed to north at one of the previous stations, unclamp the table, and turn it about until the needle again points to north. Clamp the table, which will then be oriented. Stick in a pin at a. Place the fiducial edge of the ruler against it, and turn it until the sights point to A on the ground; draw a line towards you by the ruler, and the desired point will be somewhere on this line.

Stick a pin in at b, and with the fiducial edge of the ruler against it, turn the sights on B on the ground, draw a line towards you by the ruler, and the intersection with the line drawn from a will be x, the point desired. Using C in the same way will prove the accuracy of the work.

Shifting the Paper.—When one sheet is full and it becomes necessary to replace it by a new one, to continue the survey, it may be done in the following manner:—Draw a line through the farthest point fixed from the last station. Take the sheet off the table and fix another on, drawing a line upon it in a part most convenient for the work; then cut the sheet just taken off, by the line drawn on it; apply this edge to the line on the new sheet, and as they lie in that position, continue the lines from the other station on the new paper, and prick through the positions of as many stations that have been fixed on the old sheet as you conveniently can. If the positions of three fixed points are thus transferred to the new sheet, the place of a new station can be found in the manner shown in Figs. 2 or 3. On each new sheet place the compass, and revolve the table until the needle points to north, and then draw a dark line which will represent magnetic north, unless the needle is deflected by the influence of local attraction. The better plan, if provided with a watch and sextant, will be to find the true bearings of some conspicuous object, in the manner shown on page 236, and mark it on the table.

To join the sheets together, and thus form one rough map, place the

edge of the sheet that has been cut *accurately* against the line drawn on the new sheet, and with the aid of the ruler, see that the line projected on the new sheet from the last station (on the sheet that has been removed), is an exact continuation of the corresponding line on that sheet.

Broken Survey.—The directions given above comprise briefly the fundamental rules of more accurate plane-tabling.

A map, however, may be, and often must be, constructed without the continuous connection of fixed points from sheet to sheet, as is above suggested, and which, in the rough work of an ordinary journey, is frequently impossible.

The traveller may often find that the station from which he wishes to observe rays is beyond the limits of his last sheet, and that none of his fixed points will fall upon it.

In this case he must assume a convenient point on his board as his position, turn the board in a suitable direction with regard to what he wishes to do, and sighting, if possible, one of his old stations, draw a line towards it. Should another former station be visible, another line should be drawn to it. The magnetic meridian must also be drawn by means of the compass. These three lines will enable him to place his new sheet in proper relation to his former one, by arranging them with the meridian lines parallel, and moving one until the continuation of the lines passes through the two former stations. They can then be pasted together in that position, joining them by another strip of paper, if necessary.

Even should there be no fixed stations in view, rays drawn to objects he wishes to fix will be useful, always supposing that he can afterwards fix the position by rays drawn from other stations, never omitting to place the magnetic meridian on the sheet.

New bases must occasionally be measured, and it will be found that one of the chief charms of such surveying lies in surmounting difficulties in the construction of the map. Devices for so doing will suggest themselves in increasing numbers as the traveller gains experience.

Though reliance on the compass should be avoided if possible, from its uncertainty, owing to local attraction, recourse must frequently be had to it, and under favourable circumstances, plane-tabling by its aid gives excellent results.

Concluding Remarks.—On leaving a station, the traveller, when possible, should leave some distinguishing mark behind him, so that he may be able to recognise it again. Where it is possible, as will frequently be the case, he must carefully note the changes which take place in the landscape during his march; he will also do well to write on the plane table sheets the native names of such hills, or conspicuous objects, as he may have fixed on the table, as natives generally know these objects again when viewed from another station, which, from their changed appearance, a stranger would be very unlikely to do. Paper mounted on very thin cloth, and cut to the size of the plane table, will be found serviceable, as it will not easily tear, and can be rolled up and kept in a tin case until wanted. The traveller should also provide himself with a waterproof case into which he can slip the plane table in the event of heavy rain.

From each station draw in the features of the ground around it as far as you are able. Rough sketches, made in a sketch-book, will help to complete the drawing, and the work from other stations, when you have obtained the rays from them.

A pocket (or box) sextant is a valuable adjunct for plane-tabling, as in certain cases the objects may be so crowded in one direction as to confuse the rays if they are all drawn on the board. Angles measured and recorded in a note-book can be plotted hereafter when working up the plan in the tent.

The scale on which to work must depend entirely on the nature of the country, and the objects in view. For a small tract of country, with much detail, one inch to the mile is good. For more extended areas two or four miles, or even more, to the inch is sufficient.

Remarks on the Plane Table.—By Lt.-Col. H. H. Godwin-Austen, F.R.S.

The Plane Table is one of the most useful instruments that an explorer can take with him, and the most accurate for the large areas of country he usually has to deal with; not of the small size constructed in this country, but one similar to those used in all extended survey operations in India. Its excellence lies in simplicity, which recommends it strongly for the traveller or for reconnaissance work. All additions made to it,

all attempts at converting it either into a theodolite, or a level, detract from its value, its portability, and possibility of repair if damaged. It is a simple table and nothing more, and if required to be kept out of sight will pass as such in the eyes of inquisitive natives—complicated brass work readily excites suspicion, from the fact that they do not understand what use it can be for, and any attempt to explain matters only increases their distrust.

A plane table, 2 ft. 6 in. × 2 ft., can be made light, of good seasoned deal (panelled). The traveller should take two of this size, and have his paper properly projected, with latitude and longitude on a scale of 8 or 10 miles to the inch, the former of which will embrace an area of 232 × 184 miles, leaving an inch margin, although a plane table can be worked up to the extreme edge. On this scale I have worked successfully in Assam and the Naga Hills, and for fixing the position of peaks and hills, &c., at long distances it is invaluable. The tripod-stand is available for the other instruments, but even this is not required on all occasions, as a temporary tripod-stand can be made in a few minutes with three sticks tied together in the middle.* Even when the atmosphere is too hazy to see distant objects, or the traveller is passing through a forest-country, traverse work with prismatic compass can be projected upon the plane table, or the astronomical positions plotted in, and the plane table work resumed as soon as circumstances permit. Better still than using a prismatic compass, is to gum a fresh sheet of paper by its edges upon the plane table, and on some convenient scale, say 1 inch to the mile, the route can be sketched by back and forward rays, and setting the plane table by compass. This route-sketch can then be reduced and entered on the smaller scale plane table section.

A far wider area of country is sketched in by this method than by the use of the prismatic compass, an instrument which cramps the observer (especially a young one), so that the result of such surveys is generally a long line of route with but little work on either side, and that little confined to a mere mile or two. It is improbable that error will creep into the plane table work; whereas a few errors in recording prismatic compass

* When surveying the Bhutan Himalaya from Darjiling to Punakha, after losing my plane table stand in the snow, crossing the Tegong-La, I worked on very well with such a stand for several weeks.

bearings or distances can never be corrected, often never discovered, unless the ground is gone over again. The plane table sketch is made on the spot, the country is put in as seen by the eye at the time, and when the traveller reaches camp, or his breakfasting-place, he can ink it in. If he be travelling in a dangerous country, where he may have to leave any of his equipment, and make for some other place—not an unlikely contingency at times—he has only to keep a copy of his work on tracing cloth, filling it in from time to time to carry in his pocket. During the year of the Indian Mutiny, when working in the Kashmir territory, under circumstances which rendered the survey liable to be stopped at any moment, we followed this plan by Captain Montgomerie's order, and, had anything happened, not a square mile of country finished would have been lost.

I do not think that the accuracy of plane table work, or the rapidity with which it can be done, is known and appreciated in this country. To show its accuracy, I once tested it over about 80 miles in direct line on the scale of four miles to the inch, when carrying the triangulation across the Naga Hills from Assam into Manipur. I worked with a plane table, and fixed the points on it, at the same time sketching the country, and it proved wonderfully exact when the triangles came to be computed, and the trigonometrical stations projected on it. It does not take longer to set up and commence working on a plane table than to get out a prismatic compass. About four times, or more, the number of bearings can be taken with the former than with the latter in the same time, while the plane table bearings have the merit of being absolutely true, and are all observed, and laid down the next moment, with a stroke of the pencil, and after practice almost in the exact position on the paper. No set of angles laid off with the best protractor can be so accurate.

The different value and extent of the work in Afghanistan, and at the Cape, executed during the late campaigns, shows conclusively the value of plane table survey over the prismatic compass.

As a practical illustration :—Working at the same time with an officer of the Quartermaster-General's Department on service, making a sketch of a fort and country round, my plane table survey was finished and traced off when he had only begun the plotting in his tent. The run of the mountain-spurs around such a position could never have been entered on a plan produced from a field book.

There is no measuring, no counting of paces or noting of time by

a watch, no anxiety about the record, when plane-tabling. Between the intervals of setting up the board, the traveller can be botanizing, geologizing, or collecting objects of Natural History, and in the evening, when he comes in from his work of the day, he can sort and label his specimens and write up his journal, the greater part of which leisure time he would have to give up to the plotting of the day's work, if done with prismatic compass.

One of the objections often brought against the use of the plane table, is its size and weight. This would be true if the traveller had to carry it himself. According to my experience in Asia, and what I know of Africa, where labour is, as a rule, plentiful and cheap, a plane table can always be carried by a native of the country, who at the same time would take the aneroid and boiling-point thermometers. In India the guides often carried the stand. It is seldom that a European is called on to carry anything in a tropical country. The plane table can be made as light as a gun or rifle, and reduced in size (2 ft. × 1½ ft.), together with a light tripod-stand, could be carried by any lad of 15 or 16, as was formerly the method of instruction at the R. M. C., Sandhurst.

Another objection raised is the possibility of its getting spoilt by wet. This is very easily avoided. It should slip into a waterproof bag, and if used in a very wet climate, such as the Khasi Hills, a small waterproof sheet can be thrown over all. After working with it for years, and having sketched many thousand square miles of every kind of country from dead level plains to the highest parts of the Himalaya, I never got one injured, and I never had one brought in by any of my assistants spoilt or injured in the least.

There is nothing about it to be broken, or get out of order, the sight-rule is of so simple a construction, any village blacksmith can make one should it get lost; and I once had to do this, cutting out the woodwork myself, and getting a native workman in the village to make the back and forward sights out of copper coins. The stand is easily repaired. The traveller should take a spare clamping-screw, and a spare compass.

The compass-box should be of narrow oblong form, having a perfectly plane surface beneath, so as to lie flat on the board, not fixed to the plane table (as was done in the Sandhurst pattern). The needle should be at least 4 inches in length, and the north and south ends of the compass-box should have an arc graduated a few degrees on either side of the central

line. At the first station where the plane table is set up and adjusted by the surrounding projecting points or the first rays taken, the compass-box is to be placed on some convenient part of the plane table, and moved until the needle points exactly to the centre division of the graduated arc. A pencil line should then be drawn along one side of the compass-box, against which line it will always have to be laid when setting up the plane table by it.

But here I may call attention to another strong point in favour of the plane table, and that is, that it can be used quite independently of the compass, in places where local attraction is great, and where, as I have often found, the magnetic needle is quite unreliable, throwing the plane table out many degrees, an error which would not be discovered if working with a prismatic compass. With three fixed points on the plane table, it can be set up in true position by interpolation (see p. 175). This method, however, should be resorted to only for filling in details. For extended work, the plane table should be set up, wherever possible, on rays taken from previously fixed stations.

Surveying with the Tacheometer.

(*For description of this instrument, see p.* 120.)

The method of surveying with such a tacheometer as that shown (page 121), is, as regards fixing positions of distant objects, the same as with the prismatic compass. This instrument has, however, this advantage over the prismatic compass, that distant objects are seen much more distinctly through the telescope, and the bearings can therefore be more accurately taken than when the ordinary sight vanes, of the prismatic compass, are used. In addition to which, the compass is larger than the prismatic compass usually carried by the traveller. The principal advantage of the tacheometer, however, will be found when it is employed for fixing positions within comparatively short distances. This is done by sending an assistant to the spot it is desired to fix, with a staff such as is shown (fig. 2, p. 123), and with the micrometers, measuring the angle it subtends when held (either horizontally or perpendicularly) at right angles to the line of sight, at the same time taking the compass

reading through the prism. With the angle measured by the micrometers, if a ten-foot staff has been used, knowing the value of the micrometer divisions, the distance of the object can be at once obtained from table XXIV. With the distance so found, and the bearing which has been taken, the position of the object can be at once laid down on the survey by setting out the bearing from the point of observation, and then measuring the distance, taken from the scale of the map.

With any other length of staff than ten feet, table XXIV. (p. 307) cannot be used, and the distance of the object will have to be computed. It is usual when observing the angle subtended by the staff, to measure half of it with each micrometer, the sum of which measures, will, of course, be the whole angle subtended. The distance from the staff is computed in the following manner:—Multiply the total number of divisions used in *each* micrometer by the value of a single division of that micrometer, add the results together, and this will be the value of angle in *seconds*. Divide the length of the staff, in feet, by the angle in seconds and multiply the result by the cosecant of 1″ = 206265. This will give the distance between the instrument and the staff, in feet.

Example:—Length of staff, 12 feet; divisions used, Left Micrometer, 581·9, value of each division, 2″·31; Right Micrometer, 575·2, value of each division, 2″·04.

	Left Micrometer.		Right Micrometer.
	581·9		575·2
	2·31		2·04
	5819		23008
	17457		11504
	11638		1173·408
	1344·189		1344·189
ft.		The angle in seconds =	2517.597
Log. 12 =	1·079181		
Log. 2517·6 =	3·400986		
	$\bar{3}$·678195		
Cosec. 1″ = 206265 Log. =	5·314425		
Log. distance in feet, 983·2 =	**2·992620**		

The rod, though convenient, is not, however, absolutely necessary, as distances can be measured by this class of tacheometer without it, by making an assistant set up two staves at a carefully-measured distance

from one another, and at right angles to the line of sight. The angle subtended by these staves is measured with the micrometers, and the distance computed in the manner already shown.

A tacheometer with fixed hairs, such as described (page 123), may often be used for measuring distances approximately when it is impossible to read the markings on a graduated staff. This is done in the following manner:—An assistant should be sent to the object, the distance of which is required, and directed to place a staff in the ground. The surveyor must then cover the staff with one of the fixed hairs in the instrument, after which the assistant must move, very slowly, in a line at right angles to the line of sight until he is covered by the second fixed hair, when he might be stopped by some pre-arranged signal, and place another staff there. He must then carefully measure the distance between these two staves, which distance multiplied by the ratio between the value of the hairs, which is generally 1 in 100, will be the distance of a point, midway between the two staves, set up by the assistant, and the observer. Thus, if the measured distance between the staves was 10 yards, the distance from the instrument would be $10 \times 100 = 1000$ yards.

Surveying on the tacheometer principle, but without a tacheometer, may be carried to greater distances in the following manner.

Supposed a densely wooded plain over which it has been impossible to preserve any record of the distance travelled, but with elevated country at its extremities, the distance between points on the elevated lands may be very accurately found by measuring a base on one at right angles to the position on the second, of such a length that it will subtend an angle of two or three degrees to an observer at the second point; and marking these ends either by choosing conspicuous trees or other marks, or by flashing from them with a mirror, or by making fires. The observer obtains the angle by a sextant or theodolite between the ends of the base, and by simple right-angled trigonometry calculates the distance.

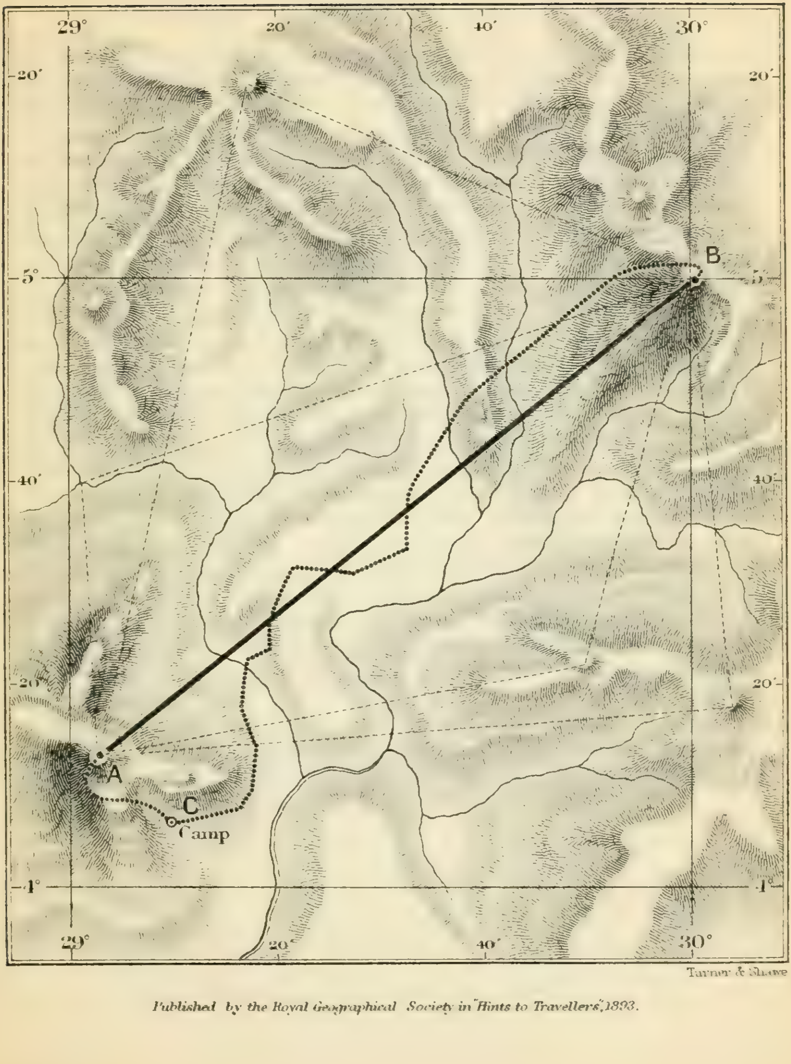
Surveying a Country and fixing positions by means of Latitudes and Azimuths.

This system of surveying can be used with advantage in a country the surface of which is so varied as to present several prominent and distant objects.

In order to use this method the traveller must first prepare a Mercator's projection that will include the area he intends to map. The reason for making choice of Mercator's projection is, that a line of bearing drawn on it will intersect every parallel and meridian at the same angle, thereby allowing all relative bearings to be readily and correctly laid down by straight lines, which could not be done on a map on any of the other projections in common use. After having prepared his projection, a reference to the annexed map will show the traveller how he should proceed.

The first thing to do is to fix the position in latitude and longitude of the starting point A. This may be done by traverse, or bearings from some object, the position of which has been fixed, or by one of the methods mentioned in this book. Having done this, he should from the summit of A, look for some prominent and distant object, in the direction he is about to travel, such as the hill B on the map, and find its true bearing by measuring its angular distance from the sun by the method shown (p. 236). If a sextant is used all such measurements must be reduced to the horizon, as shown in the example p. 238. When a transit theodolite is employed no such reduction is required, and it will only be necessary to make the hill B his zero point, and then observe the altitudes of the sun, with the vertical circle face right, and face left, in pairs (as explained p. 115), noting the times, altitudes, and horizontal angles. With the times and altitudes he must compute the sun's true azimuth (p. 239), and by applying the mean of the horizontal readings to this, he will obtain the true bearing of B.

The next step will be to set off, indefinitely, this line of bearing from A, and the point B will be somewhere on that line. Having thus obtained the true bearing of B, the true bearing of any object in sight can be at once known by measuring the angular distance between it and B. Or, if furnished with a plane-table, regarding B as the other end of the base



Published by the Royal Geographical Society in "Hints to Travellers," 1893.

and drawing rays to each object, marking each ray in such a manner as to prevent any future mistakes as to the object through which the ray is drawn.

We will now suppose that the traveller proceeds in the direction indicated on the map, meeting with obstacles which prevent his keeping in a direct line towards B, and that he allows his watch to run down, thus losing his Greenwich time, or the time of such other place as he has chosen for his reference meridian, and that after several days' march he finds himself in the vicinity of B. There he will have an opportunity of fixing the position of B, finding the error of his watch on his reference meridian, and by using this station (B) as one end of his base, and drawing rays on his plane table through the points from which rays were drawn at A, making a sketch map of the country through which he has passed. In order to do this he must ascend B, and take observation by north and south stars for latitude. The mean of results so obtained ought to be very near the truth. Suppose, in the present instance, that the latitude so found was 5° N., then by placing the straight edge on that latitude on each side of the graduated meridians, and drawing a line between those two points, its intersection with the line of true bearing of B drawn from A, will be the place of B on the map. Again, placing the straight edge on the point of intersection of this parallel of latitude and the line of true bearing of B from A, and then moving it until it is parallel with the graduated meridian, it will cut the graduated parallel in the longitude of B, which in this case is 30° E. Knowing the latitude and longitude of B, the error of the watch on the reference meridian can be found by the methods given, pp. 201, 209, 210.

The weak point in this system of surveying is, that it cannot be employed when the direction of the line of route apprcaches east or west, as the angle between the parallel of latitude and the line of bearing would be too acute to give satisfactory results.

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SURVEYING AND ASTRONOMICAL OBSERVATIONS.

PART 4.

ASTRONOMICAL OBSERVATIONS.

NECESSITY FOR ASTRONOMICAL OBSERVATIONS.

A TRAVELLER merely passing through a tract of country cannot hope to make more than a rough map of a belt extending a short distance on either side of his path.

Upon the estimation of the length of his daily march, and of its mean direction, his map will mainly depend.

The degree of accuracy of these two important factors will depend upon his experience, upon the trouble he takes to find means of ascertaining his speed, and upon his power of estimating the mean value of a course made up probably of an infinite number of windings and deviations.

When isolated or other well-marked hills exist, he may, however, on camping for the night, be able to get a bearing with his compass of an elevation at or near his point of departure in the morning, which will give a greatly improved value to the direction of his day's march.

It is, however, evident, that after a few days, especially in densely-wooded country, his position may be very much in error, and hence the necessity, if he wishes his map to be in any degree trustworthy, of fixing his position from time to time by astronomical observations, by sextant or otherwise.

These have two objects: to obtain latitude and longitude.

The latitude observations, hereafter described, are comparatively simple, and, in the case of latitude by meridian altitude, depend solely on the altitude observed.

Longitude observations are, however, more complicated, and, *whatever* method is employed, *require accurate local time.** This can be found by altitudes of the sun or stars at some distance from the meridian, noting the time by the watch, and by these observations the error of the watch on local time is obtained.

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* An exception is the case of the method of moon culminating stars.

By repeating the observation in the same spot after the lapse of a few days, the daily rate of the watch can be obtained; and, supposing the watch to be in good order, and well taken care of on the march, this rate will for some days afford a means of finding the difference of longitude of any two places when observations for time have been taken.

The precise method of doing this will be hereafter described, but it is not often that in an ordinary journey it can be employed, as it requires a halt of several days from time to time, and, moreover, it is not easy to ensure the watch from accidents.

The longitude is, therefore, more ordinarily obtained from lunars or other "absolute" observations.

It must be remembered that in all observations with the sextant, unless they are so taken as to eliminate the errors of the instrument, great errors of result may occur.

With a sextant in good order and adjustment the errors are small, and, if known, may be applied; but the heat of the sun may induce temporary errors, and shocks more serious and permanent errors, which, in some observations, will have a disastrous effect.

The ordinary observations are :—

Sextant Observations.

For latitude	Meridian altitude of sun
	,, ,, star
	Circum-meridian altitude of sun
	,, ,, star
	Double altitude of sun
For longitude	Time by single altitudes of sun
	,, ,, ,, star
	,, equal altitudes of sun
	,, ,, ,, star
	Lunar Observations.
For true bearing ..	By altitude of the sun
	By observed angular distance of a peak, or any other object from the sun

Telescope Observations :—

For longitude	Occultations of stars by the moon
	Eclipses of Jupiter's satellites
	Moon culminating stars.

Observations of heavenly bodies with the sextant.

Before any good results can be expected from sextant observations, the observer must be able to read the angles quickly and accurately; the only way to become proficient in doing this, is by practising with the instrument, especially at night, when the angles have to be read by the light of a lantern.

Methods of obtaining accurate results.—From the presence of the different sources of instrumental error mentioned on p. 102, it is necessary, in order to ensure accurate results, that observations should be taken so as to eliminate them.

The precise methods will be described under the head of each observation, but the general principle is, that any altitudes for any purpose should be balanced by others taken in the opposite direction, either by waiting until the heavenly body has travelled to the opposite side of the meridian, as in observations for time, or by observing another body on the opposite side of the zenith, as in meridian observations of a star for latitude.

Owing to the instrumental errors acting in different directions on the results in each case, the mean of those results will be the true time, or latitude, as the case may be.

For ordinary purposes of rough mapping, these niceties are not necessary, but the traveller who wishes to obtain a good determination of an astronomical position must pay regard to them.

To observe the altitude of the sun, using an artificial horizon.—Fill the trough of the horizon with quicksilver, and put on the roof. Put down the suitable shades before the index and horizon glasses, set the index of the sextant to zero (0°); then with the artificial horizon between yourself and the sun, retire, looking into the horizon, until you see the sun's reflected image in it; look through the telescope collar, or plain tube, and horizon glass of the sextant at the sun itself; unclamp the index, and move it forward. This will bring the reflected image down, follow it with the eye until it slightly overlaps that in the horizon; clamp the index, and screw the inverting telescope into the collar (no time should be lost in doing this, or the sun's image may pass out of the field); then with the tangent screw make the contact perfect. It is always better to bring the object

down into the horizon without the telescope; by so doing time is saved, and the unpractised observer is less likely to be mistaken as to which limb he is observing. The following rule will, however, prevent any such mistake:—In the forenoon, or when the sun is rising, if the lower limb is observed, the images are continually separating; if the upper limb is observed, they are continually overlapping; and the contrary in the afternoon, or when the sun is falling. When the telescope is fitted with a dark shade to screw on to the eye end, it should be used instead of the moveable shades. If a roofed artificial horizon is used, the sides should be plainly marked, and it should be reversed at each set of three altitudes, *except when equal altitudes are observed* to find the error of the watch, in which case the observations must be taken with the same side of the roof towards the observer.* In placing the horizon on the ground it should have one of the glazed sides of the roof in a direct line with the sun, so that its sides cast no shadow. Any object seen in the mercury appears to be just as much below the horizontal plane as it really is above it; all angles, therefore, observed in an artificial horizon must be halved, *after* the index correction has been applied.

The foregoing remarks apply equally to stellar observations, the only difference being that no dark shades are required.

Observations for Latitude.

The simplest observation is that for finding the *latitude by meridian altitude of the sun, star, or planet.* Some twenty minutes before apparent noon, when the sun is observed, or before the time of meridian passage of a star or planet, the observer should begin to take careful observations, reading the angles from time to time until the body has reached its greatest altitude; this will be the meridian altitude, and the time when it was taken will be apparent noon, if the sun has been observed.

Latitude by Meridian Altitude of Sun.

July 12th, 1882.—At a place in longitude by account 70° 00′ W., the meridian altitude of the ☉̲ was observed in quicksilver to find the

* This is by way of precaution against irregularities in the glass plates; and, with a roof of known excellence, is hardly necessary.

latitude. Ther. 88°. Bar. 29·6 inches. Index error—2′. Observer south of the ⊙.

	H.	M.	S.
Time of App. noon, July 12th ..	0	0	0
W. Long. in Time	+4	40	0
G. App. Time, July 12th ..	4	40	0
	°	′	″
Declination (P. i. NA.) ..	21	57	56·8 N.
Correction	−	1	37·8
Reduced Declination	21	56	19 N.
			″
Var. in 1 hour (NA.)			20·99
Hours and min. of G. A. T.			4·66
			12594
			12594
			8396
			60) 97·8134
Corr. .. .. =		1	37·8

	°	′	″
Alt. ⊙ in quicksilver	114	49	28
Index error	−	2	00
	2) 114	47	28
Observed Altitude .. .. =	57	23	44
Refraction — Ther. 88°, Bar. 29·6 ..	−	00	34
	57	23	10
Semidiameter	+	15	46
	57	38	56
Parallax		+	4
	57	39	00
	90	00	00
Zenith Distance	32	21	00 S.
Declination	21	56	19 N.
Latitude	10	24	41 S.

To Find Time of Meridian Passage of Star.

When a star is observed for latitude, it is necessary to find the time of its meridian passage, either by tables (which give an approximate result), or, where accuracy is required, by the following method.

At a place in longitude 30° E. required the mean time of the meridian passage of *Aldebaran*, on November 29th, 1881.

		H.	M.	S.
Case (1.)	R. A. of *Aldebaran* + 24h.* =	28	29	11
	Sidereal Time at Mean Noon	16	34	2
	Approx. M. T. =	11	55	9
	11h. Retardation 1m. 48·13s.; 55m. ,, 9·01s.	−	1	57
		11	53	12
	30° E. Long., or 2h. Acceleration		+	20
	Mean Time of Meridian Passage =	11	53	32

* When the star's R. A. is less than the Sidereal Time at Mean Noon, increase it by 24 hours.

At a place in longitude 60° W. required the mean time of the meridian passage of *Antares*, on July 20th, 1881.

		H.	M.	S.
Case (2.)	R. A. of *Antares*	16	22	11
	Sidereal Time at Mean Noon	7	53	37
	Approx. M. T. =	8	28	34
	M. S.			
	8h. Retardation 1 18·64 ; 28m. ,, 4·59	−	1	23
	60° W. Long., or 4h. Acceleration*	−	0	39
	Mean Time of Meridian Passage =	8	26	32

* When the Longitude is W. subtract the acceleration, when E. add it.

Latitude by Meridian Altitude of a Star.

July 10th, 1882.—At a place in longitude by account 70° 00 W., the meridian altitude of *α Aquarii* was observed in quicksilver to find the latitude. Ther. 34°. Bar. 30 inches. Index error + 3′ 10″. Observer south of the star.

	°	′	″
Alt. of ✳ in Quicksilver	90	59	42
Index error	+	3	10
	2) 91	2	52
	45	31	26
Refraction Ther. 34°, Bar. 30	−	00	59·5
True Alt.	45	30	26·5
	90	00	00
Zenith Distance	44	29	33·5 S.
Declination	0	53	13·4 S.
Latitude	45	22	46·9 S.

When the *meridian altitudes of a star above and below the Pole* can be observed, half the sum of the corrected altitudes gives the latitude at once, without any computation. When the *Pole Star* can be observed the latitude is very easily found by the rule and tables given in the 'Nautical Almanac'; and as a fairly correct approximation without any calculation at all, the corrected altitude of the Pole Star is the latitude, if the star is observed when β and ζ, or still better, when β and ε *Ursæ Minoris* appear to the eye to be in the same horizontal line; a method which, as a rough observation, has the advantage of being independent of watch, tables, or 'Nautical Almanac.'

Circum-meridian observations, or observations near the Meridian.

A latitude by meridian altitude depends only on one altitude, the highest observed, and as this is liable to error, being only one observation, a more accurate result can be obtained *by taking sets of altitudes on either, or both sides of the meridian*, and noting the time corresponding to each altitude by a watch whose error on apparent time at place is known. These altitudes are taken in the manner previously described, and the observations should be commenced at about a quarter of an hour * before the heavenly body observed comes to the meridian, and may be continued until it has passed it by a like space of time. As the sun or star will be rising very slowly, the observations should be taken with deliberation, at about minute intervals. Should the sky become overcast, the observations on either side of the meridian can easily be reduced to the meridian altitude, and this circumstance adds considerably to the value of this class of observation, as the meridian altitude may be lost.

A latitude obtained by either the meridian or circum-meridian altitudes of the sun, or stars, which are all on one side of the zenith, *i.e.* all either to the north or south of the observer, is liable to considerable errors from the existence of instrumental errors.

To get a more certain result it is necessary to determine the latitude from the mean of results of observation of north and south stars, by which the instrumental errors are eliminated, and a very exact latitude obtained.

By north and south stars are meant stars which pass the meridian to the north and south of the observer's zenith. If their altitudes are nearly the same the exactitude of the result will be much increased, on account of the elimination of errors of refraction.

Latitudes by stars of the same altitude north and south afford the traveller a fair means of ascertaining the centering error of his sextant for the altitude observed, which is one half the difference of the latitude by the respective stars. When the latitude resulting from the star on the equatorial side of the observer is less than that from the star on the polar side, the correction for centering error will be minus, and *vice versâ*.

* Very good results may be obtained from observations with a star half an hour or more from the meridian, if the local time be accurately known.

Latitude by Altitudes of a Star or Planet, near the Meridian.

On April 5th, 1880, the following observations were taken of *α Leonis* (*Regulus*) when near the meridian, to determine the Latitude, watch being 2 h. 18 m. 2 sec. slow of G.M.T. Index error 1′ 30″ minus. Lat. nearly 51° 24′ 30″ N.; Long. 0° 9′ 39″ W. The star south of observer.

	Times by Watch.				Alt. Art. Hor.			
	H.	M.	S.		°	′	″	
	6	43	25		102	18	40	
		44	30			19	10	
		45	40			19	30	
		47	4			19	00	
		48	10			18	25	
5)		228	49	5)		94	45	
Mean .. =	6	45	45·8		102	18	57	= Mean.
Error of Watch +	2	18	2	Index error	−	1	30	
G.M.T. .. =	9	3	47·8	2)	102	17	27	
				Obs. Alt. =	51	8	43·5	

	H.	M.	S.
✳'s Right Ascension. .. .. .. =	10	2	1·6
Sidereal Time (P. ii. N. A.) .. =	00	56	39·3
April 5th—			
Approximate Time of Transit =	9	5	22·3
W. Longitude in Time .. .. =		+	38·6
Approximate G.M.T. of Transit	9	6	00·9

	H.	M.	S.
Sidereal Time (P. ii. N. A.)	00	56	39·3
Acceleration for { 9 hours		1	28·5
6 mins.			1·0
1 sec.			·0
Mean ⊙'s Corrected R.A. .. .. =	00	58	8·8
✳'s R.A.	10	2	1·6
Time of ✳'s Transit at Place .. =	9	3	52·8
Longitude in Time		+	38·6
G.M.T. of Transit	9	4	31·4
Error of Watch on G. M. T. slow	2	18	2
Time by Watch of Transit .. =	6	46	29·4

(*Continued on p.* 196.)

Watch Times.	Differences, Mean Time.*	Nos. from Table No. X., or table 49 Raper.	Meridian Zenith Distance (nearly).
Watch shows H. M. S. 6 46 29 at ✱'s Transit.			
H. M. S.	M. S.		° ′ ″
6 43 25	3 4	18·6	
6 44 30	1 59	7·7	Decl. 12 32 57·4 N.
6 45 40	0 49	1·3	Lat. 51 24 30 N.
6 47 4	0 35	0·7	M.Z.D. 38 51 32·6
6 48 10	1 41	5·6	M. Z. D. = Decl. + Lat. when of different names; Decl. ∼ Lat. of the same name.
		5) 33·9	
		N. = 6·78	

	°	′	″		
Latitude ..	51	24	30	Cos	9·795022
Declination ..	12	32	57	Cos	9·989496
M. Z. D. ..	38	51	33	Cosec ..	0·202450
N.	6·78″			Log ..	0·831230
Log. Reduction	6·58			.. .. =	0·818198

	°	′	″
Observed Altitude	51	8	43·5 S.
Refraction		−	47·1
	51	7	56·4
Reduction		+	6·6
Meridian Alt.	51	8	3
	90	00	00
Meridian Zenith Dist.	38	51	57 N.
Declination	12	32	57·4 N.
Latitude	51	24	54·4 N.

* The differences of Mean Time are found by taking the difference between Watch Times, and the time of Transit, or Meridian passage, shown by Watch. When the mean time differences are great they must be converted into sidereal intervals by the table of Time Equivalents in the Nautical Almanac.

N.B.—If the object be a Planet, the Declination and Right Ascension must be corrected for the G.D. by the Daily Diff. (Mean Time N. A.)

The following will illustrate the manner in which this observation is taken. Suppose that on the 1st of December, 1881, we wished to fix the position of the Society's Observatory in latitude, by north and south stars. On looking at the heavens we should see that γ *Pegasi* and γ *Cephei* were well situated for that purpose, and with these stars' right ascensions and the sidereal time at mean noon (taken from the 'Nautical Almanac'), we should find that γ *Cephei* passed the meridian, to the *north*, at 6h. 51m. 24s., and γ *Pegasi* to the south at 7h. 23m. 57s., thus leaving an interval of 32m. 33s. between the meridian passages. We should commence observing altitudes of γ *Cephei* at 6h. 35m., and continue to do so until 7h. 5m.; we should then turn to γ *Pegasi*, and continue our observations of that star until 7h. 40m. We should then compute the latitude by each set of observations, and take the mean of their results as the true latitude. This observation may be taken, at the same place, at considerable intervals between the times of the two stars' meridian passage, and indeed days have sometimes been allowed to elapse before the second set of altitudes has been taken; the results, nevertheless, being quite satisfactory. When possible, however, it is better that the two observations should be taken consecutively, so as to ensure similar conditions of weather and refraction.

Latitude by Double Altitude.

When clouds prevent the altitude of the sun being observed at or near enough to noon to obtain the meridian altitude, or when the sun when on the meridian is too high for observation in artificial horizon, the method known as double altitude may be very useful. This consists in observing the altitude of the sun (or star) at two times differing not less than two hours from each other. The latitude can be calculated from these with great exactness. The error of the watch or local time is only required approximately.

Latitude by Double Altitudes of Sun.

October 11th, 1893, in Latitude, by estimation, 55° 30′ N., and Longitude 83° 15′ W., the following Altitudes of ⊙ were taken in an Artificial Horizon to determine the Latitude. Index error + 1′ 58″.

Times by Watch. H.	M.	S.		Alt. ⊙ in Artificial Horizon. °	′	″
7	45	00	A.M.	18	0	40 S.
10	35	00	A.M.	50	7	00

		H.	M.	S.
Time of 1st Alt., Oct. 10th		19	45	00
Time of 2nd Alt., Oct. 10th		22	35	00
*Interval = 2)		2	50	00
½ Interval	=	1	25	00
Time of 1st Observation	+	19	45	00
Middle Time at Place, Oct. 10th		21	10	00
W. Longitude in Time	+	5	33	00
†Middle Time, Greenwich Date, Oct. 11th	=	2	43	00

		°	′	″
⊙'s Declination, Oct 11th		7	12	57 S.
Corrected by Hourly Diff.	=	+	2	33
Corrected Declination	=	7	15	30 S.
		90	00	00
⊙'s North Polar Distance	=	97	15	30

* When a star is used the mean time interval must be converted into a sidereal interval by the table of Time Equivalents in the 'Nautical Almanac,' or by table 23 of Raper.

† The exact time either at place or at Greenwich is not necessary; it is the interval of time alone between the two observations which must be known with accuracy, and a good common watch will always measure it with the desired precision.

			°	'	"
1st Altitude ☉ in Artificial Horizon		=	18	00	40
Index error		=	+	1	58
		2)	18	2	38
			9	1	19
Refraction = − 5' 54" ; Semid. = + 16' 4" ; Parallax = + 0' 8"	.. ..	=	+	10	18
True Altitude		=	9	11	37
1st True Altitude		=	9	11	37
2nd True Altitude		=	25	18	37
Sum of Altitudes		2)	34	30	14
½ Sum of Altitudes		=	17	15	7

		H. M. S.		
Half Interval		1 25 0	Sin.	9·559234
		° ' "		
Declination		7 15 30	Cosin.	9·996506
Arc 1	=	21 4 18	Sin. =	9·555740
Ar. Co. Log. of Sin. of Arc 1				0·444250
		° ' "		
Half sum Alts.	=	17 15 7	Cos.	9·980707
Half diff. Alts. ..	=	8 3 30	Sin.	9·146690
		° ' "		
Arc 2	=	21 51 37	Sin.	9·570947

			°	'	"
2nd Altitude ☉ in Artificial Horizon ..		=	50	7	00
Index error		=	+	1	58
		2)	50	8	58
			25	4	29
Refraction = − 2' 4" ; Semid. = + 16' 4" ; Parallax = + 0' 8"	.. .. ..		+	14	8
2nd True Altitude		=	25	18	37
1st True Altitude		=	9	11	37
Difference of Altitudes		2)	16	7	00
½ Difference of Altitudes		=	8	3	30

.. ..			Sin.	9·101552
.. ..		° ' "	Sec.	0·030058
Arc 2		82 13 6	Cos.	9·131610
Arc 3* ..	=	97 46 54	.. Rep. Sec. Arc 1	0·030058
.. ..			Sin.	9·472134
.. ..			Cos.	9·995690
.. ..			Arc 2 Sec.	0·032408
		° ' "		
Arc 4		70 10 47	Cos. =	9·530290
Arc 5 †		27 36 7	Sec.	0·052475
			Sec. Arc 2	0·032407
		° '		
Latitude .	=	55 20 N. =	Cosec. =	0·084882

* When Latitude and Declination are contrary names, the supplement of the Cosine is Arc 3.

† In Tropical Latitudes, when the Latitude and Declination are the same names, and the Latitude is less than the Declination, the sum of Arcs 3 and 4 will be Arc 5, otherwise their Difference is Arc 5.

Time.

Measures of time.—In these pages reference is made to *Mean*, *Apparent*, and *Sidereal* times, and it is possible that a few remarks on these different measures of time may be useful to those travellers who have not had the advantage of previous instruction. The first of these, *Mean time*, is the easiest to understand, as it is that usually shown by watches and clocks, and is reckoned by the average length of all the solar days throughout the year. For the purposes of everyday life, the day is divided into two periods of twelve hours each, and commences at midnight. This is called the *civil day*, to distinguish it from the astronomical day, which commences at *noon*, and is counted through the whole twenty-four hours from one noon to another.

Apparent time is time measured by the sun, as, for instance, the time shown by a sundial, and the difference between this time and the time shown by an ordinary watch, is called the *equation of time*, or the interval of time necessary to convert *Mean* time into *Apparent* time, or the contrary.

Sidereal time is measured by the interval occupied by a star between two consecutive passages over the same meridian, which is equal to 23h. 56m. 4·09s. of our ordinary, or mean time. It will thus be seen that the *sidereal* hour is 9·83s. shorter than the *Mean time* hour, and the *Sidereal* day 3m. 55·91s. shorter than the *Mean solar* day. Tables for converting Sidereal time into Mean time, and *vice versâ*, are given in the 'Nautical Almanac' and most works on practical astronomy.

To find a lost Date.—It will sometimes happen that from one cause or another, a traveller may lose count of the day of the month, in which case (if provided with a sextant, artificial horizon, and 'Nautical Almanac' for the year), he may find it by one of the following methods:—

Find the latitude of the place by the meridian altitude of a fixed star (for this it is not necessary to know the day, as a star's declination varies but little). On the next day, at the same place, observe the meridian altitude of the sun, from which find the true altitude, and subtract it from 90° to get the sun's zenith distance; then with the latitude found by the star, and this zenith distance, the sun's declination may be found as follows:—The difference between the latitude by star and the sun's zenith distance equals the sun's declination. With the declination thus found

search page 1 for the month in the 'Nautical Almanac,' and opposite the declination that most nearly agrees with the declination found as above, is the day of the month.

This method cannot always be used in the tropics, *unless the traveller is provided with a transit theodolite*, as the meridian altitude of the sun will, at times, be too great to be measured with a sextant, when using an artificial horizon; neither can it be used with any degree of certainty at those periods just before or after the sun has obtained its greatest declination, viz., June 21st and December 21st.

Another simple method of finding the lost day, is to measure with a sextant the angular distance between the moon and one of the heavenly bodies whose distance from the moon is given in the lunar distance tables of the 'Nautical Almanac.' This observed distance must then be reduced to the *apparent distance* in the following manner:—When the sun is one of the objects, add the semi-diameters of the sun and the moon to the observed distance, but when a star or a planet is observed the moon's semi-diameter must be subtracted when the distance to the moon's far limb has been observed, but added when the near limb has been observed; the result in each case will be the apparent distance. Then (since the true and apparent distances cannot differ by more than the sum of the corrections of their altitudes), with the apparent distance found as above, search the 'Nautical Almanac' tables for the nearest given distance (of the same body) to it, opposite which will be found the day of the month. It must be remembered that the hours given in the lunar distance tables are counted from noon, when the astronomical day begins: thus July 18th. XVh., astronomical date, is July 19th, 3h. A.M., civil date.

Observations for finding the Time and Longitude.

These are of two kinds. (1) Observations which have for their object to find the difference of longitude between the place of the observer and that of a place whose longitude is known.

(2) Observations to find the longitude directly, without reference to any other position on the earth, or, as it is termed, absolutely.

The first, which are almost solely used at sea, require, when the time since the rate of the chronometer was last ascertained is great, a good and carefully-guarded timekeeper, and is known by the name of "meridian

distance," or measuring the difference between the meridian of the place and that of the place where the chronometer was last rated, whose longitude is known. This method, when applicable, is by far the best, but in travelling requires that a continuous chain of observations should be taken from the time of leaving a place whose position is known; and as a watch, carried either by a pedestrian, or on horseback, cannot be expected to keep an equable rate, the points where halts must be made for rating must not be more than five or six days apart.

It is therefore but little used in ordinary travelling, but, as it is of great value on occasions, is described hereafter.

The second method depends, in its various forms, almost entirely upon the rapidity of the moon's motion in the heavens, and, while it gives the longitude without reference to any previous observation, the result is always more or less rough, unless a great many observations are made on different nights, when the mean may approximate to the truth.

In any of these observations the true time at the place is required, and the method of finding this will first be described.

To find Error of Watch by Absolute Altitudes.

In finding local time by this observation it is not necessary that the longitude of the place should be known with any great degree of accuracy, as the Greenwich date, obtained by the longitude in time, is only used for correcting the elements taken from the 'Nautical Almanac,' and a considerable error in longitude would not produce any serious error in the declination or equation of time. The body should be observed as far from the meridian as possible, because, when nearly E. or W., errors, both of latitude and observation, produce the least effects on the hour angle. As a general rule, this observation should not be taken unless the sun or star is changing its altitude by *at least* 6′ in 1 m. of time. The readings of the barometer and thermometer should be noted, but for an approximate result are not necessary.

July 5th, 1881, at a place in lat. 18° N., and approximate long. 14° W., when a watch, supposed to be 2 h. 20 m. slow of local mean time, showed 5 h. 30 m. A.M., the altitude of the ☉ was taken in an artificial horizon to find apparent and mean time, and the error of the watch on each time at the instant of observation. Index error + 6′. Ther. 75°. Bar. 29·2 inches.

	H.	M.
Approximate local time, July 4th, allowing for supposed error of watch	19	50
Long. 14° W. =	+	56
G. D. App. time, July 4th =	20	46

	°	′	″
Declination, July 5th	22	45	54 N.
Corr. by var. in 1 hour		+	46
Reduced Declination	22	46	40 N.
	90	00	00
Polar Dist. .. .. .. =	67	13	20 N.

	M.	S.
Equation of Time, July 5th	4	19·51
Corr. by var. in 1 hour	−	1·36
Reduced Eq. Time .. .. .. =	4	18·15

	°	′	″
Observed Alt. ⊙ in Art. Horizon	60	42	40
Index Error	+	6	0
	2) 60	52	40
	30	26	20
Corr. Refraction	−	1	31
	30	24	49
Semidiameter	+	15	46
	30	40	35
Parallax		+	7
True Alt. .. .. =	30	40	42

	°	′	″		
Alt.	30	40	42		
Lat.	18	00	00	Sec. =	0·021794
P. D.	67	13	20	Cosec. =	0·035262
	2) 115	54	2		
½ Sum	57	57	1	Cosine	9·724813
½ Sum - Alt.	27	16	19	Sine	9·661068
	H.	M.	S.		
	4	14	12	= Log. sine sq. =	9·442937
	24	00	00		
App. time at place, July 4th	19	45	48		
Time by watch + 12 h.	17	30	00		
Watch slow on Apparent Time .. .. .. =	2	15	48		

	H.	M.	S.
App. time at place, July 4th	19	45	48
Equation of time	+	4	18·4
Mean time at place, July 4th	19	50	6·4
Time by watch	17	30	00
Watch slow on Mean Time .. .. =	2	20	6·4

When the error of the watch on Greenwich, *or on any other meridian* and its daily rate, are known, the longitude may be found by absolute altitudes of a heavenly body, as shown in the following examples:—

Longitude by Chronometer, from Altitudes of the Sun.

This observation was taken with a sextant and artificial horizon, P.M. at place:—

		°	′	″
Latitude	..	51	31	00 N.

Thermometer. 43°. Barometer. 29·8 inches.

1881. Times by Watch.		H.	M.	S.
Month. Day.				
March 29.		3	37	38
		3	38	25
		3	38	55
	3)	10	54	58
		3	38	19·3
Error slow on G.M.T. =			+	34·3
		3	38	53·6
Accumulated Rate =			−	38
G. D. March 29		3	38	15·6

☉'s Alt. in Quicksilver.		°	′	″
		49	39	40
		49	17	10
		49	9	00
	3)	148	5	50
= Mean	=	49	21	56·7
Index Error		−	4	00
	2)	49	17	56·7
Obsd. Alt.	=	24	38	58·3
Corrected *Refraction		−	2	7
		24	36	51·3
Semid...	=	+	16	2·6
		24	52	53·9
Parx.			+	8
True Alt.	=	24	53	1·9

Original error of Watch ..	March 10th 34·3 secs. slow.			
Daily Rate	2 secs. gaining			
Interval	19 days.			
Accumulated Rate	38			
	°	′	″	
Declin. March 29th Page II. N. A.	3	32	48·1 N.	
Hourly Diff.	+	3	30	
Sun's Red. Decln.	3	36	18·1 N.	
	90	00	00	
Polar Dist. .. .. =	86	23	41·9 N.	

	M.	S.
Eq. Time, Page II. N.A.	4	45
Hourly Diff.	−	2·7
Red. Eq. Time =	4	42·3

+ to App. Time

* When great exactness is required, note Ther. and Bar., and correct Refraction by Tables 32 and 33 of Raper, or by any similar table.

	°	′	″		
Altitude	24	53	1·9		
Latitude	51	31	00	Sec.	0·206009
Polar Dist.	86	23	42	Cosec	0·000860
Sum	2) 162	47	43·9		
½ Sum	= 81	23	51·6	Cosin.	9·174858
Difference between Alt. and ½ Sum	= 56	30	50	Sin.	9·921176

Log. Sin. Sqr. H. M. S. 3 33 1 ... = 9·302903

A good time to take sights is when the sun is about 4 hrs. from the meridian.

If the sights are A.M., subtract the Hour ∠ from 24 hrs. and the remainder is App. Time at Place reckoned from preceding day.

	H.	M.	S.	
Hour ∠	3	33	1	
	00	00	00	
	3	33	1	= App. Time at Place.
	+	4	42·3	= Eq. Time.
	3	37	43·3	= Mean Time at Place.
	3	38	15·6	= G. M. T.
			32·3	= Long. in Time = 0° 8′ 4·5″ W.

To find the error of the watch on mean and apparent time at place :—

	H.	M.	S.
Mean Time at Place by Observation	3	37	43·3
Time by Watch	3	38	19·3
Watch Fast on M. T. at Place	00	00	36
Equation of Time	+	4	42·3
Watch Fast on App. Time at Place		5	18·3

Longitude by Chronometer, from Altitudes of a Star.

	°	′	″
Latitude	51	24	13 N.

Arcturus W. of Meridian { July 6th. Watch 11 secs. fast on G. M. T. Rate, gaining 2 secs. daily. Ther. 60°, Bar. 30 inches.

Time by Watch.

Year. Month. Day.		H.	M.	S.
1881. July 12		11	14	26
		11	17	19
		11	19	54
	3)	33	51	39
Mean	=	11	17	13
Error of Watch..			−	11
		11	17	2
Accumulated Rate			−	12
Month. Day. G. M. T. July 12	=	11	16	50

Alt. of ✳ in Art. Horizon.

		°	′	″
		59	37	00
		58	44	00
		57	54	00
	3)	176	15	00
Mean	=	58	45	00
Index Error		−	3	00
	2)	58	42	00
		29	21	00
Refraction— Ther. 60 .. .. Bar. 30 inches	}	−	1	41·6
True Alt. ..	=	29	19	18·4

		H.	M.	S.
✳'s R. A. (N. A.)		14	10	17
		°	′	″
✳'s Declination (N. A.) ..	=	19	48	5 N.
		90	00	00
✳'s Polar Distance	=	70	11	55 N.
Date.		H.	M.	S.
Sider. Time (N. A. p. ii.) July 12		7	22	4·50
Acceleration for 11 hours ..	=		1	48·42
,, 16 min. ..	=			2·63
,, 50 sec. ..	=			·14
Mean Sun's R. A. ..	=	7	23	55·69

N.B.—When the Star is to the West of the Meridian, add the hour ∠ to the Star's R. A.; when to the East, subtract the Star's hour ∠ from its R. A. (increased if necessary by 24 hours); the result is the R. A. of the Meridian; from the R. A. of the Meridian (increased if necessary by 24 hours), subtract the R. A. of the Mean Sun, and the result will be the Mean Time at place of observation.

		°	′	″		
✳'s True Alt.	=	29	19	18·4		
Latitude	=	51	24	13	Sec.	0·204933
Polar Distance	=	70	11	55	Cosec.	0·026469
Sum	2)	150	55	26·4		
½ Sum	=	75	27	43·2	Cosin.	9·399715
½ Sum − Alt.	=	46	8	24·8	Sin.	9·857958
		H.	M.	S.		
✳'s Hour ∠	=	4	29	51	= Log. Sin. Sqr. =	9·489075
✳'s R. A.	=	14	10	17		
R. A. of Meridian		18	40	8		
Mean Sun's R. A.		7	23	55·69		
Mean Time at Place		11	16	12·3		
G. M. T.		11	16	50		
Longitude in Time	=			37·7	= 00° 9′ 25″·5 West.	

To find the error of the watch on **mean and apparent time** *at place*:—

	H.	M.	S.
Mean Time at Place by Observation	11	16	12·3
Time by Watch	11	17	13
Watch Fast on M. T. at Place	00	1	0·7
Equation of Time	+	5	25·0
Watch Fast on App. Time at Place	00	6	25·7

Equal Altitudes of the Sun, Star, or Planet.—In consequence of instrumental errors, time obtained by absolute altitudes is sometimes considerably in error.

To eliminate these, it is necessary to observe *equal altitudes* of the heavenly body—that is, to note the time when it is at the same altitude east, and when west, of the meridian.

This necessitates a halt of some hours, and, in the case of a star, observation in the night and early morning; but when time and circumstances are favourable, the result will always be more satisfactory than absolute altitudes.

This observation must be commenced when the heavenly body observed is three or four hours east of the meridian. Having placed the artificial horizon in its proper position, bring down the reflected image of the object with the sextant until it is in contact with the image in the horizon, then advance the index until it points to a whole degree—for example, 40°—and, looking through the telescope at the image reflected by the sextant mirrors, wait until it attains this altitude, note the time, advance the index 20′, to 40° 20′, and wait until this altitude is reached, note the time; again advance the index 20′, to 40° 40′, and in like manner wait till this altitude is attained, note the time. Repeat this operation as often as convenient; nine such observations will be ample. The heavenly body observed will, of course, at some time, have the same altitude when it is west of the meridian, and this will be the case when it is *about* the same interval, in time, from it. The observer must therefore watch until the last altitude taken is again furnished, note the time when this takes place, and couple it in his note-book with the time when the heavenly body had the same altitude on the other side of the meridian; move the index *back* 20′ and wait until this altitude is furnished, note the time, and again couple it with the time when the same altitude was before taken, and so on through the set, moving the index *back* after each sight by the exact amount it was moved forward when the object was east of the meridian, or rising. When an artificial horizon is used, equal altitudes of a star should be taken in preference to those of the sun, for as the images of the star are but small luminous points, there cannot be any great error in the observation if they are made to touch, while in the case of the sun, exact contacts are by no means so easy to make. The computation necessary to find the error of the watch, by equal altitudes

of a star, is extremely short and simple, and therefore best suited to the ordinary traveller. As the declination of a star may, for the purposes of this observation, be considered constant, there is no necessity to compute the equation of equal altitudes, which must always be done in the case of the solar observation. The number of minutes by which the index is to be advanced or put back must depend on the rapidity with which the heavenly body is changing its altitude; it has here been mentioned as 20′ to illustrate the manner in which the observation is taken; but no general rule can be given for this; it is a matter in which the observer must use his own discretion. The same side of the roof of the artificial horizon must always be used for both sets of observations.

To find the Error of a Watch by Equal Altitudes of the Sun.

March 18th, 1881.—Latitude, 51° 30′ 40″ N. Longitude, 0° 8′ 12″ W.

Times of ⊙'s Equal Alts. by Watch.							
	A.M. H.	M.	S.		P.M. H.	M.	S.
	10	11	9		14	00	16
	10	17	15·5		14	6	15
2)	20	28	24·5	= Sums = 2)	28	6	31
Mean of A.M. Times	10	14	12·2	Mean of P.M. Times	14	3	15·5
				Mean of A.M. Times	10	14	12·2
				2)	24	17	27·7
Middle Time by Watch					12	8	43·8 = M.

	H.	M.	S.
Mean of P.M. Times..	14	3	15·5
" A.M. "	10	14	12·2
Difference .. .. 2)	3	49	3·3
Half Elapsed Time	1	54	31·6 =

	Year.	Month.	Day.	H.	M.	S.
	1881	March	18	00	00	00
W. Longitude in Time..					+	32·8
Greenwich Date at Apparent Noon .. .. =				00	00	32·8

	Month.	Day.		°	′	″
⊙'s Declination (p. i. N. A.)	March	18	..	00	46	31·0 S.
Corr. for Hourly Diff. (N. A.)					−	0·6
Corrected Declination				00	46	30·4 S.
Polar Distance, decreasing				90	46	30·4 N.

	M.	S.
Equation of Time (p. i. N. A.)	8	5·8
Corr. for Hourly Diff. (N. A.)		0
Corrected Equation of Time, + to App. Time	8	5·8

		″
Hourly Diff. in Declination (N. A.)		59·25
Half Elapsed Time	×	1·9
	C =	112·575

	H.	M.	S.
If the Watch is right for Apparent Time, it will show	12	0	0
But it shows	12	8	23·9
Therefore it is Fast for App. Time at Place		8	23·9

	H.	M.	S.
Applying Equation of Time to	12	0	0
Equation of Time	+	8	5·8
If right for M. T., at App. Noon the Watch would show	12	8	5·8
But it shows	12	8	23·9
Therefore Watch Fast on M. T. at Place ..			18·1

	H.	M.	S.
Applying Long. in Time to M. T. at App. Noon	12	8	5·8
Longitude in Time		+	32·8
Corresponding G. M. T...	12	8	38·6
But Watch shows	12	8	23·9
Watch Slow on G. M. T. at Apparent Noon			14·7

C		112″·6	Log. ..	2·051538	To find A.
Lat. ..	51° 30′ 40″		Tang. ..	0·099567	
h	1h. 54m. 31s.·6		Cosec. ..	0·319481	
		A. 295″·5 =	Log. =	2·470586	

C		112″·6	Log. ..	2·051538	To find B.
Decl. ..	0° 46′ 30″·4		Tang. ..	8·131205	
h	1h. 54m. 31s.·6		Cotang. ..	0·262829	
		B. 2″·79 =	Log. =	0·445573	

The sum of A and B, when the Lat. and Decl. are contrary names, or their difference, when they are the same name, is the Equation of Equal Altitudes. Divide this Equation by 15, and the result is the Equation expressed in time.

	H.	M.	S.
Middle Time by Watch	12	8	43·8
*Equation of Equal Altitude	–		19·87
Time by Watch at Apparent Noon	12	8	23·93

* + when ☉'s P. D. is increasing, but – when ☉'s P. D. is decreasing.

NOTE.—When the Lat. and Decl. are the same name, and the Declination greater than the Latitude, B may be greater than A. When the Latitude is equal to, or exceeds the Declination, A will be greater than B.

Q

To find the Error of the Watch by Equal Altitudes of a Star.

Example.—On August 10th, 1879, in lat. 51° 22′ N., long. 00° 10′ W., Equal Altitudes of the star *α Cygni* were taken, when the watch showed as undermentioned; required the error for Mean Time at the place of observation when the star passed the meridian:—

Watch Times of Equal Altitudes.

	H.	M.	S.
α Cygni E. of Meridian	8	45	10
,, W. ..	13	20	15
2)	22	5	25
Time by Watch, of Star's Transit	11	2	42·5

To find Time of Star's Transit.

	Month.	Day.	H.	M.	S.
Star's R. A.	August	10th	20	37	21·98
Sidereal Time. p. ii. N. A.	,,	,,	9	14	22·59
Time of Star's Transit at Place (nearly)			11	22	59·39
10′ W. Longitude, in Time .. .. =				+	40
Greenwich Date of Star's Transit (nearly)			11	23	39·39

Mean Sun's R. A.

	Month. Day.	H.	M.	S.
Sidereal Time, p. ii. N. A.,	August 10th	9	14	22·59
Acceleration for G. D. of transit (23)	11 h.	+	1	48·42
	23 m.	+		3·78
	39 sec.	+		0·11
Mean ☉'s R. A. corrected	=	9	16	14·90

To find Error of Watch.

	Month.	Day.	H.	M.	S.
Star's R. A. ..	August	10th	20	37	21·98
Corrected Mean ☉'s R. A.	,,	,,	9	16	14·9
Corrected Date of Star's Transit at Place			11	21	7·08

	H.	M.	S.
Therefore Watch should show	11	21	7·08
But it shows	11	2	42·5
Error of Watch on Mean Time at *place* when Star passed Meridian .. .. =	00	18	24·58 slow

Equal Altitudes of a Star on the same side of the Meridian, on different nights.—Observe the altitude of a star at any time, note the time and the altitude. After an interval of some days—for example, four days—set the index to the altitude noted, and take the time when the star attains it; then, as a star comes to the meridian exactly 3m. 55·91s. earlier every day, multiply this interval by the number of days elapsed, and subtract the product from the time when the first altitude was taken; the result will be the time the watch should show. Any difference between this result and the time the watch shows is the error for the interval, which, divided by the number of days, gives its daily rate; thus, if a watch showed 9h. 50m. 8s., when an observation of a star was

taken June 20th, and on June 24th showed 9h. 34m. 10s., when the same star had the same altitude, its daily rate would be 3·6s. losing:—

	H.	M.	S.
1st time	9	50	8
3 m. 55·91 sec. × 4 =		15	43·6
Time watch should show	9	34	24·4
2nd time	9	34	10
Losing in 4 days			14·4 ∴ daily rate 3·6 sec.

This observation should only be taken when the star has a considerable altitude, so as to reduce the errors caused by refraction, and can only be used when a halt of some days is made, as any change in latitude would be followed by a change of altitude.

Rate.

It is but of little practical use to find the precise time of your observation unless it is transferred to the watch. By taking the difference between the time resulting from the observations, and that shown by the watch, the error of the latter is found.

The true time of any subsequent, or previous observation taken within a short time of the observation for time, can then be found by applying this known error to the watch time.

If, however, the time is required some days later, it is necessary to know the rate of the watch, and this is obtained by repeating the observation for time in the same spot after a few days, when the difference of the errors, divided by the time elapsed between the observations, will be the rate of the watch.

	H.	M.	S.
Thus, Error of Watch at Ujiji on 24th Sept., 8 A.M., was	1	14	23 slow
" " " 29th Sept., 8 A.M., was	1	15	17 "
Difference		5) 54	
Rate of Watch =			10·8 losing

Then, supposing that observations for longitude, say, by lunars, were obtained on the 26th without being able to obtain observations for time

on the same day, the time can be found by applying the rate to the previous error, thus:—

	H.	M.	S.	H.	M.	S.
Watch showed at time of observation for lunar about 10 P.M.				9	1	50
Error of Watch on 24th .. .. =	1	14	23			
2·6 days' rate = 28·1 secs. losing			28·1			
Error of Watch at time of lunar	1	14	51·1 ..	1	14	51·1
True time at observation, 26th				10	16	41·1

Longitude by Meridian Distance.

The difference of longitude of two places is the difference of time between them at the same instant.

If therefore you can transport the time at one place, by means of a watch, to another place, and obtain the true time at that second place, the difference of those times is the difference of longitude between the two places.

This is accomplished in practice, by finding the errors of the watch at the two places, either by absolute, or equal altitudes, and the rate, in any case at one of them, though it is better to find it at both, and take the mean.

The difference of longitude is then thus found.

	H.	M.	S.
Error of Watch at Mombasa, 8 A.M., 14th of July	2	18	32 slow
,, ,, ,, 9 A.M., 20th ,, ...	2	17	14 ,,
Interval 6·04 days Difference =		1	18
6·04)			78
Daily rate =			12·91 gaining,

	H.	M.	S.
Error of Watch at Taveta, 4 P.M., July 25th	2	8	5 slow.
,, ,, ,, 8 A.M., July 30th	2	6	48 ,,
Interval 4·67 days. Difference =		1	17
4·67)			77
Daily rate .. .. =			16·5 gaining.
Former daily rate .. .. =			12·9 ,,
			2)29·4
Mean daily rate			14·7 ,,

		H.	M.	S.	
Error of Watch at Mombasa, July 20th, 9 A.M. ..	=	2	17	14 slow.	
5·3 days' mean rate	–		1	18 gaining.	
Error of Watch at Mombasa, July 25th, 4 P.M. ..	=	2	15	56 slow.	
,, ,, Taveta, ,, ,, ..	=	2	8	5	
Meridian distance, or difference of Longitude between Mombasa and Taveta	=		7	51	= 1° 57′ 45″

and as the watch is less slow at Taveta than at Mombasa, Taveta is west of Mombasa.

	°	′	″
The Longitude of Mombasa being	39	40	00 E.
Meridian distance, west	1	57	45 W.
Longitude of Taveta .. .. =	37	42	15 E.

Here we have supposed the rate to be obtained at both places. If, however, it was only ascertained at one end, that rate would have to be used. In the case supposed the result would be a difference of 10 seconds in the determination of the longitude of Taveta, or 2′ 30″ of longitude.

This method can be used at *any part of a journey* to measure the differences of longitude between two places. If the longitude of one of the places has been fixed by lunars, or other absolute methods, the longitude of the other is known at once. If not, the longitude of either of the places may be fixed hereafter, and the longitudes of the places whose meridian distances have been measured will be in connection with it, and not be scattered about with large individual errors, as would be the case were they determined separately by one or two lunars. Thus Consul O'Neill, by means of a large number of lunars, settled, in 1884, the longitude of Blantyre, near Lake Nyassa, and any travellers starting from this centre can, by means of a good watch, satisfactorily determine the positions of places in connection with it.

Longitude by the Occultation of a Star.

This is the best of the absolute methods of finding longitude, when a sextant is available for ascertaining the local time. The following describes the manner in which the observation is taken :—

The moon in its monthly revolutions round the earth frequently passes

between the earth and a fixed star so as to intercept a spectator's view of the latter; the disappearance of a star from this cause is called an *immersion*, and its reappearance from behind the moon is called an *emersion*. A list of these phenomena is given in the 'Nautical Almanac,' with the limits in latitude beyond which a star cannot be occulted by the moon. As the elements refer to the moon and star, as they would be seen from the earth's centre, they serve equally for all places on the earth's surface.

This observation is much easier, and more certain in its results, than the lunar observation; as the instrument (the telescope) is one that every person can use, and is not liable to any error, all that is required is that the observer shall be certain that one instant he does see the star and that the next instant he does not (with an emersion the exact contrary is the case). Neither is there much difficulty in recognising the star, its position with reference to the moon being clearly pointed out in the 'Nautical Almanac,' and as the moon only moves its own diameter among the stars in an hour, there is ample time after the star and moon are in, apparent, close proximity to make sure of the star. Before, or immediately after this observation, a set of sights should be taken to find the error of the watch on apparent or mean time at place.

When a traveller has decided to observe an occultation, he should, during the day, find the local time of that phenomenon, by applying the assumed longitude in time to the G.M.T. of conjunction in R.A. of the moon and star, which he will find among the elements of occultations in the 'Nautical Almanac,' *adding* the longitude in time if it be *East*, and *subtracting* if it be *West*. An hour before the time so found, he should point his telescope to that limb of the moon by which the star will be occulted; it is necessary to take this precaution as his assumed longitude, and therefore his time, may be considerably in error. The moon will be seen to approach the star from west to east, until its eastern limb will reach the star and occult it; note the instant when this takes place. After a certain interval the star will re-appear on the other side of the moon; note this time also. Either of these observations are sufficient to determine the G.M.T., and thence the longitude, in the manner shown in the example. When the star is occulted by the moon's dark limb, the observation will afford most decisive results. At or near full moon a star occulted by the bright limb is not so easy an observation. The

description of a telescope suitable for this observation is given on p. 235. The example given is computed by Raper's rule and tables. It will be observed that several of the logs can be taken at one opening of the book, and as only four places of decimals are used, the log sines, cosines, &c., can be taken at sight to the nearest 30″; this is not, however, the case with the proportional logs; where they occur the strictest accuracy must be observed, and the decimals of seconds must not be neglected. This remark also applies to the Moon's Declination, Right Ascension, Horizontal Parallax, and Semidiameter.

Longitude by the Occultation of a Star.

July 3rd, 1892.—*Uranus*, immersion at Daboja (West Africa) Lat. 9° 31′ 26″ N. Approx. Long. 1° 43′ W. Watch 17 min. 36 sec. fast of local time. ☽ West of the Meridian.

	H.	M.	S.
Time by Watch of immersion	8	50	30
Error of Watch	−	17	36
	8	32	54
West Long. in Time	+	6	52
Corresponding G. D., July 3 ..	8	39	46

	′	″
☽'s Semid. p. iii. N.A. Noon	14	48·2
" " " Midt.	14	48·6
	00	00·4
Noon	14	48·2
Correction	+	·3
Corr. Semid.	14	48·5

	°	′	″
Latitude	9	31	26
Reduction (LII.)	0	3	43
Geocentric Lat.	9	27	43

		′	″
☽'s Hor. Par. Noon		54	14·2
☽'s Hor. Par. Midt.		54	15·4
12 Hourly Diff.	=	00	1·2
Corr. by 12 Hourly Diff. for G. D.	=	+	0·87
☽'s Hor. Par. Noon	=	54	14·20
☽'s Hor. Par. corr. for G. D. ..		54	15·07
Correction for Lat. (XLI.)		−	0·2
☽'s Reduced Hor. Par.	=	54	14·87

Month. Day.		H.	M.	S.
Sidereal Time, July 3 (p. ii. N. A.)		6	47	53·17
Accel. (XXIII.) { 8 H.	=		1	18·85
39 M.	=			6·40
46 S.	=			·13
Reduced Sidl. Time		6	49	18·55
Mean Time at Place	+	8	32	54
R. A. of Meridian	=	15	22	12·55
✱'s Right Ascension	−	13	59	57·27
✱'s Hour Angle	=	1	22	15·28
		°	′	″
✱'s Declination		11	42	44·9 S.

		°	′	″
☽'s Declination July 3rd at 8 hours		10	42	57·8 S.
* Variation of Decln. in 1 m. = 12·6″ × 39·8 min. of G. D.	=	+ 8		21·5
Reduced Declination	=	10	51	19·3 S.

* The variation in 1 m. is found by removing the decimal point in the difference of Declination in 10 minutes (given in the 'Nautical Almanac') one figure to the left hand.

☽'s Reduced Hor. Par. pro Log.	0·5209	.. ..	0·5209	.. .. 0·5209
Geocentric Latitude. Cosec.	0·7841	.. .. Sec. ..	0·0059	.. .. .. Sec .. .. 0·0059
✱'s Declination. Secant.	0·0091	.. .. Cosec.	0·6925	✱'s Hour ∠ Cosec. .. .. 0·4544
Arc A = 8′ 44″ = Pro Log. =	1·3141	✱'s Hour ∠ Sec.	0·0286	½ Sum of 3 Logs. .. .. .. = 0·9812
Arc C − 00 00				× 2
(A − C) = 8 44		Arc B = 10′ 10·3″ = Pro Log. =	1·2479	1·9624
				Constant .. .. + 1·5820
				✱'s Declination Cotan .. + 0·6834
				Arc C = 00′ 00″ = Pro Log. = 4·2278

	°	′	″
✻'s Declination	11	42	44·9 S.
(A−C) + when Lat. and Decl. same name .. .. − when Lat. and Decl. different name	−	8	44
	11	34	00·9
B−when Hour ∠ is *less* than 6 hours; + when *more* .. .. −	00	10	10·3
Prepared Declination .. .. =	11	23	50·6

Part I. for ☽'s Parallax in R. A.

	°	′	″		
Prepared Declination ..	11	23	50·6	Cosine	9·9913
☽'s Declination	10	51	19·3	Constant ..	1·1761
Difference		32	31·3		
☽'s Semidiameter ..		14	48·5		
Difference ..		17	42·8	½ Pro Log. ..	0·5035
Sum.		47	19·8	½ Pro Log. ..	0·2901
	m.	sec.			
Part I. =	1	58·15	= Pro Log. = ...		1·9610

Part II.

.. .. Cosine	9·9913
.. .. Constant.. ..	1·1761
‖ Sum of 3 Logs. used to find C.	0·9812
Part II. 1 M. 16·7 s. = Pro Log.	2·1486

		H.	M.	S.
✻'s R. A.		13	59	57·27
Part I. { If Immersion .. .. − If Emersion .. .. + }	−		1	58·15
		13	57	59·12
Part II. { When ☽ E. of Merid. .. .. .. − When ☽ W. of Merid. .. .. .. + }	+		1	16·7
☽'s Right Ascension .. .. =		13	59	15·82

	H.	M.	S.			
(1) ☽'s R. A. (thus found)	13	59	15·82			
(2) ☽'s R. A. preceding hour, viii. h. ..	13	58	0·84			
(3) ☽'s R. A. following hour	13	59	50·05		Constant	0·4771
Diff. between (1) and (2)		1	14·98		Pro Log.	2·1586
Diff. between (2) and (3)		1	49·21		Ar. Co. Pro Log.	8·0048
	00	41	11	=	Pro Log. .. .. .. =	0·6405
Hour of (2) .. .. +	8					
** G. M. T.	8	41	11			
Mean Time at Place	8	32	54		° ′ ″	
Longitude in Time	0	8	17	=	2 4 15 W.	

** For extreme accuracy, re-compute Part I. with this G.M.T., and the result will be the true G.M.T., possibly some seconds different from the first obtained.

N.B.—The Roman numerals refer to the Table in 'Raper.'

Lunar Observations.

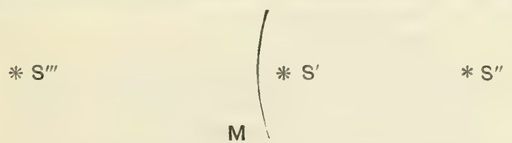
In this observation the observed distance is not only liable to errors caused by a defect of parallelism in the telescope, which always makes the observed distance too great, but to all other instrumental errors, some of which may very possibly be unknown to the observer, and as an error in the distance, of whatever kind, produces about thirty times its amount in longitude, it will be readily understood that but little value can be attached to the results obtained from a single set of lunar distances, even when the observation has been taken by a competent person, as making the contact slightly above or below the centre of the field, combined with the effects of irradiation, may very well cause an error of 20″ in the observed distance, the effect of which would be, in average cases, 600″ or 10′ error of longitude. For these reasons lunar observations cannot be recommended to any person who has not acquired a perfect knowledge of the use of the sextant, its errors and adjustments; or who is unable to remain at one place long enough to take a series of distances east and west of the moon.

To Measure the Angular Distance between the Moon and Sun.—As the enlightened limb of the moon is always nearest to the sun, the angular distance measured is always that of the near limbs; but since, on account of her comparatively feeble light, it is necessary to observe the moon by direct vision, and since the sun at the time of observation may be either to the east or the west of the moon, the sextant has to be held with its face up or down as the case may require. In *north latitude*, when the sun is to the west of the moon, the instrument is held with its face upwards; but when the sun is to the east of the moon, it must be held with its face downwards. In *south latitude* the *opposite* of this rule must be followed. This is often much easier if the observer can hold the sextant in his left hand; the position of the hand and wrist may otherwise be cramped and almost painful. Before taking an observation, look at the sun through the dark shades, and select those which reduce its brightness in the greatest degree compatible with good definition; put these down before the index glass; see that the inverting telescope is adjusted to focus; set the index to zero (0°); and hold the instrument with its plane parallel to a line joining the sun and moon; look at the moon through the telescope collar and horizon glass, and move the index

slowly forward until the sun's reflected image makes a rough contact with the moon, seen by direct vision through the unsilvered part of the horizon glass; clamp the index, screw in the telescope, and make the contact perfect in the centre of the field with the tangent screw, moving the sextant slowly round the axis of the telescope, by which means the reflected image of the sun will appear to pass the moon, and the accuracy of the contact can be tested.

Between the Moon and Star or Planet.—The angular distance between a star or planet and the moon is always measured to the moon's enlightened limb, which is often the farthest from the star or planet. When this is the case, the moon must be brought by reflection past the star or planet before the contact can be made; in other respects the observation is precisely similar to that already described, when the angular distance of the sun is taken.

In observations of this class, the utmost attention must be paid to accuracy, and a faulty habit of observation in making contacts of the moon's limb with a star is not necessarily eliminated, as is very generally supposed, and frequently stated, by taking distances east and west of the



moon. For example, if it is an observer's habit, in making a contact, to place the star within the moon's disc, M, as at S′, the distance S″ S′ is too small, and the distance S‴ S′ too great; but supposing the moon to be moving in the direction from S′ to S‴, each distance will give too early a Greenwich time, for each will give the time when the moon's limb was actually at S′. When, however, the sun is the object observed east and west of the moon, errors of this sort in observation, *if constant*, will be eliminated, since, as the moon's enlightened limb is always turned towards the sun, such errors would increase both distances and produce errors of an opposite description in the Greenwich time.* A single observation is of little value;

* For further information on this subject, read the article on Lunar Distances in '*Chauvenet's Spherical Astronomy*.'

distances should always be observed in sets, with stars east and west of the moon, and as nearly equidistant from it as possible; the observer should also note which limb of the moon has been observed, and whether the star was east or west of it. The more nearly the two bodies approach the same horizontal plane, the easier will be the observation to take, and distances between 45° and 90° will be least liable to errors in observation.

The thermometer and the barometer (or its equivalent, a boiling-point thermometer) should be noted, and the refraction corrected accordingly; because, if thermometric and barometric corrections be omitted, in observations made on a high and heated plateau, there may be serious errors in the results.

A complete pair of lunars, made wholly by one person, consists of the following observations, *in addition to those for latitude.*

An hour before beginning to observe, get everything in perfect order; see that the lamp is well trimmed, its air-holes free, and that it is filled with oil. Also rehearse the expected observations, that no hitch may occur after they have commenced. Then let the hand and eye have ample time to repose, and go on as follows:—

1. Read thermometer in air.
2. Adjust horizon-glass, if necessary.
3. Two pairs of observations for index error.
4. Three altitudes for time, star E.
5. Three altitudes for time, star W.
6. Three altitudes of moon.
7. Five lunar distances, star E. of moon.
8. Five lunar distances, star W. of moon.
9. Three altitudes of moon.
10. Three altitudes for time, star W.
11. Three altitudes for time, star E.

It is not absolutely necessary to take all of these altitudes, and it may often happen that the traveller may be prevented by circumstances from observing the altitudes of the moon and the other heavenly bodies, in which case they can be computed as shown on p. 225. For this purpose, however, it is necessary that the latitude of the place, and the exact local time when the distances were observed, should

be known. The time can be found in the manner shown on p. 201. The observation for time, the latitude of the place, and which limb of the moon was observed, should be carefully entered in the note-book for the convenience of the computer.

Clearing the Lunar Distance by Raper's Rigorous Method.—As this is one of the shortest, and at the same time a strictly accurate method of clearing the Lunar Distance, it is here given for the benefit of those travellers who may not have Raper's work in their possession.

Having found the Greenwich date with the assumed longitude in time, and the mean time at place by a watch, the error of which on local time has been found by previous observation, reduce thereto the moon's horizontal parallax and semidiameter, and if the sun be one of the objects observed, take its semidiameter from the 'Nautical Almanac.' From the observed altitudes get the apparent and true altitudes; from the observed distance get the apparent distance. Add to, or subtract from the apparent altitudes as many seconds as are necessary to bring them to odd or even minutes, then add them together and subtract their sum from 180°, and the remainder will be the sum of the Apparent Zenith Distances.

Increase or diminish the True Altitudes by the same number of seconds as were added to or subtracted from their respective Apparent Altitudes; add them together and subtract their sum from 180°, and the remainder will be the sum of the True Zenith Distances.

Add together the Log-secants of the Apparent Altitudes and the Log-cosines of the True Altitudes; the sum, rejecting tens in the index, will be the Logarithmic Difference.

Increase or diminish the Apparent Distance by any quantity of seconds necessary to bring it to an odd or even minute (noting the number of seconds); to this add the sum of the Apparent Zenith Distances; take Half the sum, and from this Half Sum subtract the Apparent Distance—call this Remainder.

To the Log-sines of the Half Sum and Remainder add the Logarithmic Difference, and the sum, rejecting tens in the index, will be the Log-sine square of the auxiliary arc x.

Arc x may also be found without any special table of log-sines square in the following manner:—When the sum of these three logs has for an index a number above 20, reject 10 from such index, and

then divide the sum by 2; this will give ½ the log-sine of the arc, which multiplied by 2 will give auxiliary arc x; *this, of course, applies to all cases where a log-sine square is mentioned.*

Under x put the sum of the True Zenith Distances, take their sum and difference and their Half Sum and Half Difference, add together the log-sines of the Half Sum and Half Difference, and their sum is the log-sine square of an arc, to which apply the same number of seconds by which the Apparent Distance was increased or diminished to bring it to an odd or even minute, subtracting them if the Apparent Distance was increased, but adding them if diminished, and the result will be the true distance nearly. Take the difference between the proportional logs in the 'Nautical Almanac' against the two distances between which the computed true distance falls. With this difference and the portion of time just found, enter the table of corrections for second differences ('Nautical Almanac' or table 57 Raper), and take out the seconds. When the proportional logs in the 'Nautical Almanac,' are *increasing*, *subtract* these seconds from the True Dist., nearly; when they are *decreasing*, *add* them, the result will be the M. T. at Greenwich.

Lunar (Raper's Rigorous Method)

	°	′	″
Latitude	51	31	11 N.
Thermometer ..	49		
Barometer	30 inches.		

Date Nov. 22nd, 1879, P.M. at place of observation, Mars and ☽. *Mars East of Meridian.*

Supposed.	H	M.	S.
Time by Watch ..	7	46	33
Accumulated Rate of Watch		−	29
	7	46	4
Error of Watch		−	8
G. M. T. Nov. 22nd ..	7	45	56

	°	′	″
☽ Semid. (table 40) ..		15	2·5
Augmentation (42) ..			9·2
☽'s Aug. Semid.		15	11·7
Mars' Declination ..	17	28	23 N.
	90	00	00
Mars' Polar Dist. ..	72	31	37 N.
	H.	M.	S.
Mars' R. A.	2	56	15

		′	″
☽'s Hor. Par. Noon		55	28·9
Mid.		55	11·2
Variation in 12 hours		00	17·7
Correction (table 21)		00	11·4
Hor. Par. Noon		55	28·9
Hor. Par. corr. for G.D.	=	55	17·5
Corr. for Lat. (41)		−	6·7
Reduced Hor. Par.	=	55	10·8

	Art. Hor. °	′	″
Mars' Observed Alt.	80	21	30
Index error	+		3
	2)80	21	33
App. Alt. .. =	40	10	46·5
Refraction − 1′ 9·1″, Par. in Alt. + 13″	−	0	56·1
Mars' True Alt. =	40	9	50·4

	Art. Hor. °	′	″
Observed Alt. ☽ ..	78	30	54
Index error	+		3
	2)78	30	57
	39	15	28·5
Augt. Semid... ..	+	15	11·7
☽'s App. Alt. =	39	30	40·2
☽'s corr. in Alt. (39)	+	41	25
☽'s True Alt. =	40	12	5·2

	Day.		H.	M.	S.
Sidereal Time at Mean Noon Nov. 22nd ..			16	4	24·24
Acceleration for G. D. (23) ..	7 hours ..			1	9
	45 min. ..				7·39
	56 sec. ..				·15
Mean ☉'s R A.		=	16	5	40·78
			°	′	″
Observed Distance F.L.			53	30	10
Index error			+	2	00
			53	32	10
☽'s Semid. Augmented		=		15	11·7
☽'s Apparent Dist.		=	53	16	58·3

	App. Alts. °	′	″		True Alts. °	′	″
Mars (+ 13·15″) ..	40	11	00	Mars (+13·5″) ..	40	10	3·9
☽'s (+19·8″)	39	31	00	☽'s (+19·8″) ..	40	12	25
Sum = ...	79	42	00	Sum	80	22	28·9
	180	00	00		180	00	00
Apparent Zenith Dists.	100	18	00	True Zenith Dists. ..	99	37	31·1

Mars App. Alt.	Sec.	0·116916
☽'s App. Alt.	Sec.	0·112698
Mar's True Alt.	Cos.	9·883184
☽'s True Alt.	Cos.	9·882933
Logarithmic Difference .. .. =		9·995731

	°	′	″		
Mars True Alt.	40	9	50		
Lat.	51	31	11	Sec.	0·206039
N.P.D.	72	31	37	Cosec.	0·020516
Sum	2) 164	12	38		
½ Sum	82	6	19	Cosin	9·137839
½ Sum − Alt.	41	56	29	Sin.	9·825017
	H.	M.	S.		
Hour ∠	3	5	16	= Log. Sin. sq.=9·189411	
Mars R. A. + 24 hours	26	56	15		
	23	50	59	= R. A. of Merid.	
	16	5	41	Mean Sun's R. A.	
	7	45	18	= Mean Time at Place.	
	7	45	51	= G. M. T. by Lunar.	
	00	00	33	= Long. in Time = 00° 8′ 15″ West.	

	°	′	″		
App. Dist.	53	17	00	(note 1·7″ added)	
App. Zenith Dists. ..	100	18	00		
Sum .. .. =	2)153	35	00		
½ Sum = ...	76	47	30	Sin.	9·988356
½ Sum − App. Dist. =	23	30	30	Sin.	9·600845
Logarithmic difference .. .. =					9·995731
Arc x	76	38	52	$=\left\{\begin{matrix}\text{Sin.}\\ \text{sq.}\end{matrix}\right\}$	=9·584932
True Zenith Dists. ..	99	37	31·1		
Sum	176	16	23·1		
Difference	22	58	39·1		
½ Sum	88	8	11·5	Sin.	9·999770
½ Difference	11	29	19·5	Sin.	9·299238
Approx. True Dist. ..	52°	59′	49″	$=\left\{\begin{matrix}\text{Sin}\\ \text{sq.}\end{matrix}\right\}$	=9·299008
Seconds added	—		1·7		
True Dist. .. .. =	52	59	47·3		
N.A. at VI. hours ..	53	55	19	pro. Log. N.A. 2805	
Difference		55	31·7	pro. Log.(74) 5108	
	H.	M.	S.		
Time of Dist. by N.A. ..	6	00	00		
	1	45	55	= pro Log = 2303	
	7	45	55		
Correction for 2nd difference (57)			4		
G. M. T. by Lunar ..	7	45	51		
Time by Watch	7	46	33		
Watch fast of G. M. T. =			42		

To compute the Altitude of a Heavenly Body.

It frequently happens that, at the time when a lunar distance is required, the altitude of one, or both, of the bodies may be so high or so low as to prevent their being taken in an artificial horizon, in which case the altitude should be computed, the error of the watch on M. T. at place having been previously determined; and since the *Altitudes* employed in clearing the lunar distance are not required to the same degree of precision as those used in finding the time, it will be sufficient if they are computed within 20″ or 30″ of the truth.

Rule.—Having taken from the 'Nautical Almanac' the declination, R.A., Sidereal Time, Semi-diameter Horizontal Parallax, &c., as required, correct the same for the *approximate* Greenwich Date.

Find the Hour Angle as follows:—

For the ☉ the apparent time from Noon is the Hour Angle. If P.M. the mean time at place converted into app. time with the equation of time will be the hour angle, but if A.M. the apparent time thus found, expressed astronomically, must be subtracted from 24 hours to give the hour angle.

For the Moon, Star, or a Planet:—

To the Sidereal time at noon on the given day (page ii. N. A.) accelerated for Greenwich date (table 23 Raper) add the mean time at place, this sum will be the Right Ascension of the Meridian; subtract from the R. A. of the Meridian the R. A. of the object, and the result will be the west hour angle of the object; which subtract from 24 hours when the east hour angle is required.

The True Altitude may now be computed as follows:—

To find arc I.—To the log cosine of the object's hour angle add the log cotangent of the latitude; their sum (rejecting 10 in the index) will be the log tangent of arc I.

To find the true Altitude.—Add together the log sine of the Latitude, the log secant of arc I., and the log cosine of the *difference* of arc I. and the Polar Dist.; their sum will be the log sine of the true Alt.

N.B.—When the hour angle is more than 6 hours, or 90°, take the log cosine of the *sum* of arc I. and the Polar Dist.

From the True Altitude to find the Apparent Altitude:—

The corrections must be applied in reverse order, and with contrary signs to those with which the true is derived from the Apparent Altitude.

For the Sun or for a Planet.—Subtract the Parallax in Altitude, and add the Refraction.

For a Star.—Add Refraction.

For the Moon.—Take out the correction in Alt (table 39 Raper), and subtract it from the True Altitude of the Moon, this gives *only* the approximate apparent altitude; enter the same table 39 again with this approximate apparent altitude, and take out the correction again, which subtract from the TRUE *altitude*—the result gives the Apparent Alt.

Computation of ☽'s true Central Altitude.

November 10th, 1879, at 7 h. 3 m. 23 secs. A.M., in Latitude 8° 48′ s., and supposed Longitude 31° 6′ E., the distance between the sun and moon was observed. The altitude of the moon was too great to admit of its being observed in the Artificial Horizon, it had therefore to be computed. The error of the watch on mean time at place had been found by previous observation to be 2 m. 8 sec. slow. Thermometer, 73° Fahr. Barometer, 27·40 inches.

		H.	M.	S.
Time by Watch Nov. 9th ..		19	3	23
Error of Watch..		+	2	8
Mean Time at Place ..	=	19	5	31
E. Longitude in Time ..	−	2	4	14
G. M. T. Nov. 9th	=	17	1	7
		H.	M.	S.
Sidereal Time Mean Noon. Page II. N.A...		15	13	9
Acceleration. 17 hours..	=		2	47·56
1 min. ..	=			·16
7 secs. ..	=			·02
Red. Sid. Time	=	15	15	56·74
Mean Time at Place ..	+	19	5	31
R.A. of Meridian ..	=	34	21	27·74
☽'s Red. R.A.	−	11	31	47·15
		22	49	40·59
		24	00	00
☽'s Hour ∠		1	10	19·41

		H.	M.	S.
☽'s R.A. at 17 hours	=	11	31	44·65
☽'s R.A. at 18 hours	=	11	33	52·62
Hourly Variation ..	=		2	7·97

Constant Log.	9·5229
Hourly Variation Pro Log. ..	1·9262
Mins. and secs. G. M. T. Pro Log.	2·2073
Corr. ☽'s R.A. + 2″·5 = Pro Log.	3·6564

		H.	M.	S.
☽'s R.A. at 17 hours ..		11	31	44·65
Corr. ☽'s R.A.		+		2·5
☽'s Red. R.A. ..	=	11	31	47·15

	°	′	″	Diff. in 10m N.A. ″
☽'s Declination ..	2	1	59·7	
Corr. (Raper XXII.)			16	
☽'s Red. Decl. ..	2	2	15·7 S	15·138
	90	00	00	
P. D. .. .. =	87	57	44·3 S.	
Arc (1)..	80	46	35·0	
S. P. D. − Arc (1) =	7	11	11·3	

	′	″
☽'s Hor. Par. midnt.	59	0·1
☽'s Hor. Par. noon	59	28·4
12 Hours' Variation..		28·3

	′	″
☽'s Hor. Par. midnt.	59	0·1
Corr. (Raper XXI.)		11·3
	59	11·4
Corr. for Lat. (Raper XLI.) ..		3·3
☽'s Reduced Hor. Par.	59	8·1

R 2

	H.	M.	S.		
☽'s Hour ∠	1	10	19·41	Cosine =	9·979220
	°	′	″		
Latitude	8	48	00	Cotan =	10·810206
Arc (1)	80	46	33	Tang. =	10·789426

	°	′	″		
Latitude	8	48	00	Sin. =	9·184651
Arc (1)	80	46	33	Sec. =	0·795073
S. P. D. − Arc (1)	7	11	11	Cosine =	9·996575
☽'s True Central Alt. ..	71	14	34 =	Sin. =	9·976299
☽'s Corr. in Alt.	−	19	2·6		
☽'s Appt. Altitude.. =	70	55	33·4		

For ☽'s Correction in Altitude (XXXIX. Raper).

		′	″
71° 10′ and 59′	=	18	43
4′	=	−	4
8″	=	+	3
		18	42
Thermometer .. .. .. 73°−0·8 Barometer.. .. 27·4 inches−1·8		+	2·6
☽'s 1st correction	=	18	44·6

		°	′	″
☽'s True Alt.	=	71	14	34
1st Correction		−	18	44·6
☽'s Approx. App. Alt.		70	55	49·4

		′	″
70° 50′ and 59′	=	19	2
5′	=	−	5
8″	=	+	3
		19	00
Thermometer .. .. .. 73°−0·8 Barometer .. .. 27·4 inches−1·8		+	2·6
☽'s correction		19	2·6

Longitude by Moon Culminating Stars.

The observation can be taken with the transit theodolite, which must, however, be accurately set up in the plane of the meridian. This can be done by either of the following methods :—

By Meridian Passage of the Pole Star.—Find the mean time of the meridian passage of the pole star in the manner shown on p. 193. Level the instrument, and if this be carefully done the line of collimation will move in a plane perpendicular to the horizon, and will pass through the zenith, then by making it also pass through the celestial pole, and clamping the horizontal plates when it is in that position, the movements of the telescope will be restricted to the plane of the meridian. This is done by turning the telescope on to the pole star, and covering it with the point of intersection of the telescope wires at the time (previously ascertained) of its upper or lower culmination, and then firmly clamping the horizontal plates. The meridian line should now be laid out to the north and south of the observer by sending a man with a lantern and a staff in both directions, and making him drive the staff into the ground at the spot where the observer sees the lantern in a central position on the cross wires of the telescope.

By High and Low Stars.—This method is accurate, and will be found convenient when the pole star cannot be observed. Having placed the instrument approximately in the meridian, choose two stars differing *considerably* in declination, and but *little* in right ascension. Note carefully the time that each star passes the central wire; take the difference of these times, to which apply the rate of the watch, due for the interval, and convert this into a sidereal interval by Raper, table 23, or by the 'Nautical Almanac' table of time equivalents. Take from the 'Nautical Almanac' the apparent right ascensions of the stars, and subtract the less from the greater. If this difference agrees exactly with the sidereal interval obtained by the watch, the telescope will move in the meridian, but when this is not the case, and the interval shown by the watch is less than the difference of the stars' right ascensions, the telescope must be moved to the *west*; if the contrary be the case the telescope must be moved to the *east*. This must be repeated until the sidereal interval, computed from the watch times of transit, and the difference of the stars' right ascensions taken from the 'Nautical Almanac,' agree exactly; the

telescope will then move in the plane of the meridian. Select a star as near the zenith as possible for the "high star," as when the instrument is truly level the telescope will be on the meridian when pointing to the zenith, no matter how much it may differ from the meridian when in any other position.

By Meridian Passage of any Star.—Any star may be used if the local time is accurately known, and the time of the star's meridian passage carefully computed (as shown, p. 192). The observation is precisely the same as for the pole star, but it would be well to take more than one star in order to correct any errors that may have been made in observation or computation. Though the results of such observations as these are susceptible of a great degree of precision, yet absolute accuracy must not be expected.

By Stars East and West of the Meridian.—If local time is not accurately known, the true meridian may be found in the following manner:—Carefully level the transit theodolite, and set the 360° division as nearly *true* north as you can get it by the attached magnetic needle, then clamp the lower plate, and unclamp the vernier plate; select any star at some considerable distance east of the meridian, and cover it with the intersection of the threads in the diaphragm, *clamp the vertical circle*, and take the reading on the horizontal plate; then, after the necessary interval, watch the star until it is again covered with the intersection of the threads in the diaphragm west of the meridian, take the reading, and then the theodolite will point just as far west of the meridian as it originally did to the east, and a point midway between these two horizontal readings will be in the true meridian. Care must be taken to keep the vertical circle and the lower plate clamped during the interval between these two observations. Having thus found the true meridian it can be marked as previously directed. Owing to the constant change in the sun's declination it is unsuited for finding the meridian by this method.

In the following:—

Æ	indicates	right ascension of the heavenly body.
☽|	,,	the moon's bright limb.
T′	,,	approximate longitude in time.
T	,,	longitude in time.
C	,,	the difference of Æ.
B	,,	the mean of the second differences of Æ.

The Observation:—Having the instrument set in the plane of the meridian, proceed as follows:—

From the list of "Moon Culminating Stars," given in the 'Nautical Almanac,' select the star whose transit you intend to observe, and calculate the local mean time of its meridian passage in the manner shown on p. 192. Take from the 'Nautical Almanac,' page IV., the moon's meridian passage (upper), and from this subtract the time of the moon's semi-diameter passing the meridian, *before full moon*, but add it *after full moon*, the result will be the mean time of transit of the moon's bright limb; but if the meridian of place of observation is at any great distance from the meridian of Greenwich, or any other meridian, from which the difference of the longitude is to be found, then it will be necessary to correct this in the manner shown in the explanation of page IV., given at the end of the 'Nautical Almanac.' All this should be done some time before the transits are to be observed.

If the instrument is fitted, as it should be, for taking transits, it will have four wires, one horizontal and three vertical, in the place of the usual web, and the exact time of the contact of both the moon's bright limb and the star must be observed at each of the three vertical wires, and the means taken as the true time of observed transit. Be sure to be ready at the instrument some time before the first object comes to the meridian, and make a note of the difference between the declination of the moon and the star, as when the moon transits before the star, it will only be necessary to move the vertical circle by that amount to ensure the star coming into the middle of the field, but if the star transits first, its altitude must be computed beforehand, and for this the latitude must be known, thus:—Add together the complement of the latitude of the place of observation and the declination of the star, when they are of the same name, or taking their difference when of contrary names; the altitude to be reckoned from the south point of the horizon when the latitude is north, and the contrary when south; but when the sum exceeds 90° it is to be taken from 180°, and the altitude is to be reckoned from the north in north latitude, and the south in south latitude.

Having taken the observation, take the difference between the observed mean of the times of transit of the ☽| and ∗, this will be the mean time interval; accelerate this (Table 23 Raper, or Time equivalents N.A.), and the result will be the sidereal interval.

Put down the Æ of the star observed, and under this put the sidereal interval just found. When the moon transits *before* the star *subtract* the interval from the star's Æ, but when the moon transits *after* the star *add* it, and the result will be the Æ of the moon's bright limb at transit at place, under which put the preceding Æ of the moon's bright limb, taken from col. 4 (N.A.) "Moon Culminating Stars," and take the difference, which turn into seconds and decimals of a second, and call C.

Take from the fourth column of the table of "Moon Culminating Stars" (N.A.) the Æ of the moon's bright limb for four successive culminations, so that two may precede and two follow the Æ of moon's bright limb at transit at place of observation; put these below each other in regular order, and subtract each of these quantities from the following for the "First Differences," and called the middle term A; subtract each of the "First Differences" from the following for the "Second Differences," and take half the sum, or mean of the "Second Differences," and call it B. The subtraction necessary to obtain the "differences" must be made as in algebra, i.e., by changing the sign of the quantity to be subtracted, and giving the result the sign of the greater quantity; take care to prefix the proper sign to B.

It should be remembered that the right ascensions of the moon's bright limb, taken from the 'Nautical Almanac,' must be those of the same limb (I. or II.) * as that observed. Near the full moon, when the limb marked in the 'Nautical Almanac' changes from I. to II., there may be one or two right ascensions not marked for the limb required. In this case the requisite right ascensions may be found by adding to, or subtracting from, the right ascension of the limb given in the 'Nautical Almanac,' *twice* the sidereal time of the moon's semidiameter passing the meridian (col. 7 "Moon Culminating Stars," 'Nautical Almanac'), and the result will be the right ascension of the other limb.

To the constant log 4·635480 (the log of 12 hours expressed in seconds) add the ar-co-log of arc A expressed in seconds, and the log of C; the sum of these three logs, rejecting 10 in the index, will be the log of approximate longitude in time, which call T′.

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* The Roman figures I. and II. indicate the limbs of the moon which come first or last to the meridian.

Enter table No. XXIII. (p. 305) with B at the top, and the approximate longitude in time, T′, at the side, and find the corresponding correction, to the log of which add the constant log 4·635480 and the ar-co-log of A, and the sum, rejecting 10 in the index, will be the log of the correction to be applied to the approximate longitude in time with the same sign as B, and thus the correct value of T will be obtained, which will express the longitude of the place if it be west of Greenwich, but if the longitude is east we must subtract this value of T from 12 hours to obtain the true longitude in time east of Greenwich.

This method, *which is entirely independent either of local or Greenwich time*, includes all that is necessary to find the difference of longitude between any two meridians where observations have been taken, but as the elements in the 'Nautical Almanac' have been most accurately computed, it is better to take Greenwich as the other meridian.

The principle upon which the longitude is found in this method is similar to that which is used in a common lunar observation, and depends on the observed motion of the moon; but in the present problem, this motion is ascertained by observing the time when the moon's bright limb passes the meridian, instead of measuring the angular distance of the moon from the sun, star, or planet. The variation of the moon's right ascension, corresponding to a change of 15° in the longitude, is given very accurately by the 'Nautical Almanac' for every transit of the moon's limb at Greenwich. This variation is about 2m. in time for 1h. of longitude, and when the difference of the times of transit under different meridians has been found by observation, it is easy to obtain the corresponding longitude.

Example.

November 28th, 1884, the transits of the ☽| and the ✱ ϵ Piscium were taken over three wires of a transit theodolite to determine the longitude of the place; the times being taken by an ordinary watch.

Transit of ☽|	H.	M.	S.
	8	12	47·7
	8	13	01·6
	8	13	16·6
	3)	39	05·9
Mean	8	13	01·97

Transit of ϵ Piscium	H.	M.	S.
	8	23	23·9
	8	23	37·7
	8	23	51·6
	3)	70	53·2
Mean	8	23	37·73

	H.	M.	S.
Obsd. Local M. T. of Transit of ϵ Piscium	8	23	37·73
Obsd. Local M. T. of Transit of ☽|	8	13	01·97
Mean Time Interval.. .. =	0	10	35·76
Acceleration		+	1·74
Sidereal Interval .. .. =	0	10	37·50

	H.	M.	S.
Greenwich Transit of ✱ Nov. 28th, 1884 (✱'s Æ col. 4 Nautical Almanac).	0	56	59·26
☽|'s Transit before ✱ (Sidereal Interval)	−	10	37·50
Æ of ☽| at Transit at Place =	0	46	21·76
Preceding Æ of ☽| (col 4 Nautical Almanac) .. .. .. =	0	45	54·39
Diff. of Æ = C =	0	00	27·37

	Nov. Day.	1884.	H.	M.	S.	1st Diff. M.	S.	2nd Diff. secs.
2 preceding Æ of ☽|	27th	L. C.	0	18	35·41			
						+ 27	18·98	+ 42·88
	28th	U. C.	0	45	54·39			
						A + 28	01·86	+ 47·77
2 following Æ of ☽|	28th	L. C.	1	13	56·25			
						+ 28	49·63	2) 90·65
	29th	U. C.	1	42	45·88			B = + 45·32

Constant Log.	=	4·635480	.. ..	4·635480
A expressed in seconds = 1681·86 Ar. Co. Log...	=	6·774211	.. ..	6·774211
			Equation from Table.	
C .. .. secs. 27·37 .. .. Log ..	=	1·437275	0″·3 .. .. .. Log.	0·477121
Approximate T′ .. .. secs. 703·0 .. = Log...	=	2·846966	Corr. + secs. 7·7 = Log. =	0·886812
Correction .. .. + 7·7				

Longitude in Time T = 710·7 = 2° 57′ 40″·5 West.*

* The Longitude is *West* because the ☽'s Æ at Transit at place is *greater* than the ☽'s Æ at the *nearest* U. C. (upper culmination) at Greenwich (which in this case was 0h 45m. 54·39s.). If the ☽'s Æ at transit at place had been *less* than the *nearest* U. C. at Greenwich, the Longitude would have been East.

*To find the Longitude by Eclipses of Jupiter's Satellites.**

In the 'Nautical Almanac' will be found the configuration of Jupiter's satellites for every day in the year, except when Jupiter is so close to the sun that his satellites are invisible; these diagrams are given for north latitude, and must be reversed for south latitude When Jupiter comes to the meridian before midnight, the whole eclipse (both immersion and emersion) takes place on the *east* side of the planet; when after midnight, on the *west* side. As an inverting eye-piece must be used, this will appear to be reversed. The error of the watch on mean time at place should be found from observations of the sun's, or a fixed star's altitude; but if Jupiter is more than 3 hours from the meridian at the time of making the immersion or emersion of one of his satellites, and if Jupiter's altitude be taken at the instant of observing the immersion or emersion, the use of a watch will be unnecessary, as the 'Nautical Almanac' will furnish the Greenwich date required; this, of course, can only be done when there are two observers. As a rule, the *first* satellite is to be preferred, as its motion is more rapid than that of the other three. The explanations given in the 'Nautical Almanac' are so clear that they leave nothing to be added.

The Observation.—Having estimated the local time of the phenomenon with the assumed longitude, and the time given in the 'Nautical Almanac,' be ready some time before the eclipse will take place, with a telescope having a magnifying power of not less than 40, and note the instant of the disappearance or re-appearance of the satellite. It must be remembered that either of these events (being caused by the shadow of the planet) may take place when the satellite is at a considerable distance from Jupiter. The difference between mean time at place when the observation was taken, and the mean time at Greenwich given in the 'Nautical Almanac,' is the longitude as shown in the following example:—

Nov. 30, 1881, observed the emersion of the 1st satellite of Jupiter,

* "This method, though easy and convenient, is not very accurate; the eclipse is not instantaneous, and the clearness of the air, and the power employed, affect considerably the time of the phenomenon. Observers have been found to differ 40 secs. or 50 secs. in the same eclipse."—*Raper*.

at 2h. 25m. 4sec., the error of the watch on *local* mean time being 36m. 33secs. slow.

	H.	M.	S.				
Time by Watch	2	25	4				
Error of Watch .. .. +		36	33				
	3	1	37				
M. T. at Greenwich ('Nautical Almanac')	10	26	16		°	′	″
Longitude in Time	7	24	39	=	111	9	45 W.

Observations for Bearings.

To find the True Bearing of a peak or any other object by means of its observed angular distance from the sun.

Observe the sun's altitude, then the angles between the object and the nearer and farther limbs, and lastly the sun's altitude again; noting the times of each contact. If the object has any altitude observe it, and note whether it is east or west of the sun. Half the sum of the times of the observed angular distances is the mean time of the observation, and half the sum of the angles observed is the apparent angle; but if the farther limb, only, be observed, the apparent angle is found by subtracting the sun's semi-diameter; or if the nearer limb, by adding. From the observed altitudes of the sun, the altitude at the time of the observed angle is found by Simple Proportion.

With time at place find Greenwich date, either by the error and rate of the watch, or with the longitude in time.

Take the declination from the 'Nautical Almanac' (if *App.* time is used, Page I.; if *Mean* time, Page II.); correct this for the Greenwich date. From the observed altitude, find the *True Alt.*

Add together { *True Altitude,*
Latitude,
Polar Distance;

divide their sum by 2 for the half sum, and take the difference between the polar distance and the half sum, which call remainder.

Add together { *Log secant of the Altitude,*
Log secant of the Latitude,
Log cosine of ½ sum,
Log cosine of remainder, } rejecting 30 from the index.

Take out the log sine square of the sum of these four logs (table 69, Raper), or divide the sum by 2, and it will give the log sine of half the true azimuth, which multiply by 2; in either case the result will be the sun's true bearing. If the observed object has an altitude,

$$\text{Add together} \left\{ \begin{array}{l} \textit{Log sine of object's alt.,} \\ \textit{Log sine of } \odot\textit{'s app. alt.,} \\ \textit{Log cosec. of app. angle,} \end{array} \right\} \begin{array}{c} \text{rejecting 20 from} \\ \text{the index,} \end{array}$$

and take out the sum as a log sine: the result is the corrected angle.

If the observed object has no altitude, or if its altitude is very small, this step is neglected, and the apparent angle is used as the corrected angle.

Find the apparent alt. from the true alt. already found, from the observed angular distance find the apparent distance, and from the cos of the dist. from ⊙'s centre, subtract the cos of the apparent altitude; the remainder will be the cosine of difference of bearings. If the sun be *East* of the meridian, and the object more *East*, or the sun be *West*, and the object more *West*, *add* the difference of bearing thus found to the ⊙'s true bearing. In any other case, take the difference between the sun's true bearing and the difference of bearings, and the result is the true bearing of the object.

When this observation is taken with a transit theodolite, the object, the bearing of which is required, is made zero before taking the altitudes, and the horizontal verniers are read after taking each altitude. As this gives the *horizontal* angle between the object and the sun, it will only be necessary to compute the sun's true bearing; and by applying the horizontal angle to this, the true bearing of the object is obtained, and the latter part of the work given in the example will be unnecessary.

Example.

$$\text{Cos difference of bearings} = \frac{\text{Cos apparent distance}}{\text{Cos apparent alt. of} \odot}$$

July 15, 1881, P.M. at place, angles and altitudes taken with a sextant. Lat. 51° 24′ N., Long. 9′ 39″ W.

Time. H. M. S.	☉ Alt. in Quicksilver. ° ′ ″	Obsd. Angular distance of an object. East of the Sun ° ′ ″
3 13 18	87 45 00	109 12 10

Year. Month. Day.	H.	M.	S.
1881, July 15	3	13	18
Error of Watch		−	13
Month. Day. G. M. T. July 15 ..	3	13	5

Month. Day.	°	′	″
Declination July 15th (Page ii. N. A.)	21	28	52 N
Correction by Hourly Diff. for G. M. T.	−	1	17
	21	27	35
	90	00	00
North Polar Dist. .. .. .. =	68	32	25

	°	′	″
Obsd. Alt. in Quicksilver ☉	87	45	00
Index Error	−	2	10
	2) 87	42	50
Obsd. Alt. .. .. =	43	51	25
Refraction	−	1	0
	43	50	25
Semidiameter	+	15	46
	44	6	11
Parallax	+		6
True Alt.	44	6	17

	°	′	″	
☉'s True Altitude	44	6	17	Sec. 0·143834
Latitude	51	24	00	Sec. 0·204899
N. Polar Distance ..	68	32	25	
	2) 164	2	42	
½ Sum .. .. =	82	1	21	Cos. 9·142341
½ Sum ∼ N. P. Dist.	13	28	56	Cos. 9·987863

☉'s True Bearing = Log. Sin. Square (69)† = S. 66° 34′ 45″ W. .. .. 9·478937

	°	′	″
Obsd. Alt. ☉	43	51	25
Semidiameter	+	15	46
Apparent Alt. ☉	44	7	11

	°	′	″	
Observed angular distance of object from the near limb of the sun, *corrected for Index error*	109	10	00	
☉'s Semidiameter	+	15	46	
Distance from ☉'s centre	109	25	46	Cos. .. .. 9·521983
☉'s Apparent Altitude	44	7	11	Cos. .. .. 9·856056
Difference of Bearings	62°	24′		= Cos. .. .. 9·665927

	°	′
Difference of Bearings* .. .. =	62	24
	180	00
	117	36

(* If the obsd. angular distance is greater than 90°, subtract this Difference of Bearings from 180°.)

		°	′	
True bearing of ☉	S.	66	35	W.
Object East of ☉		117	36	
True Bearing of Object	S.	51	1	E.

† Figures in brackets refer to the number of the table in "Raper."

Finding the error of the Compass by the ☉'s Azimuth.

The observation for finding the sun's true bearing and error of the compass is the same as that for finding apparent time, with this addition, that the bearing of the sun's centre, at the time of observation, must be taken with a prismatic or other compass.

August 12th, 1881, P.M. at place, the following observations were taken to find the error of the compass:—

	°	′	
Latitude	64	5	N.

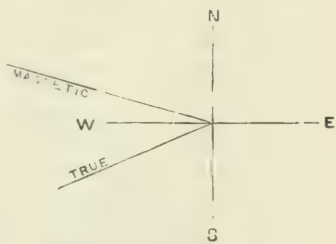
Times by Watch.	H.	M.	S.
	5	19	56
	5	21	54
	5	23	11
	3) 16	5	1
Mean .. .. =	5	21	40
Error of Watch .. .. +		4	13
G. M. T., August 12	5	25	53

	°	′	″	
☉'s Declination, August 12 ..	14	52	8	N
Corr. by Hourly Diff. .. .. .. −		4	4	
Reduced Declination	14	48	4	N.
	90	00	00	
North Polar Distance .. .. =	75	11	56	

Alt ☉ Art. Horzn.	°	′	″
	52	27	00
	52	3	00
	51	41	20
	3) 156	11	20
Mean .. .. =	52	3	46
Index Error = +		2	00
	2) 52	5	46
Obsd. Alt. ..	26	2	53
Refraction .. −		1	59
	26	0	54
Semi-diameter .. +		15	49
	26	16	43
Parallax .. .. +			8
True Alt .. =	26	16	51

	°	′	
Bearing of ☉	N. 71	6	W.
	180	00	
	S. 108	54	W.

* When the true Azimuth is to the *left* of the magnetic the variation is W.; when the true Azimuth is to the *right* of the magnetic the variation is East.



	°	′	″	
Alt. .. .. .. =	26	16	51	Secant 0·047385
Lat. .. .. .. =	64	5	00	Secant 0·359456
N. P. D. .. .. =	75	11	56	
	2) 165	33	47	
½ Sum .. .. =	82	46	53·5	Cosine 9·099181
½ Sum − N.P.D. =	7	34	57·5	Cosine 9·996186

9·502208 = Log. Sin. Square = S. 68 38 W. ☉'s True Azimuth.
S. 108 54 W. ☉'s Bearing.

Error of Compass = 40 16 W.*

On Observations with Theodolites or Altazimuth Instruments.

By General J. T. Walker, R.E., C.B., F.R.S., LL.D.

In the opening pages of these Hints, lists of instruments have been given which travellers of little experience are recommended to provide themselves with, and the sextant has been more particularly recommended, as the traveller will have opportunities of practising with it under the tuition of the officers of the ship which is conveying him to his destination.

The suitability of this instrument for observations, both on land and sea, is thus a great advantage for any person who has not had an opportunity of learning the use of his instruments before starting on his expedition; and should he not have a sufficient knowledge of the methods of reducing the observations and calculating the results, he will find the simplest and easiest rules for his guidance in the several works on navigation, which are specially devised to enable the reduction of observations with sextants to be made by persons possessing little or no knowledge of the principles on which the rules are based.

But the extent of the regions of *terra incognita* in which inexperienced travellers can operate with the greatest advantage is constantly becoming more and more narrowed and diminished, and geographical science now-a-days frequently requires that the rough outlines which have hitherto sufficed for her purposes, should not only be amplified and filled in, but rectified by more exact and reliable observations. The traveller must, in such cases, be provided with an instrument of greater capabilities than the sextant, and he should have thoroughly learnt the use of this instrument and the method of reducing the several kinds of observations which may be made with it, before he commences operations. If he has no better instruments nor greater skill than his predecessors, his results may differ widely from theirs, but they will not be more worthy of confidence.

An altazimuth instrument—or a theodolite possessing a complete vertical circle as well as a horizontal circle—is in many respects superior to a sextant. 1st, it measures horizontal angles directly, thus avoiding the labour of reducing oblique angles to the horizon; and a round of several angles can be measured with far less trouble than with the sextant. 2ndly, it measures small vertical angles of elevation or de-

pression of objects which frequently could not be seen by reflection from a mercurial horizon for the measurement of the double angle by a sextant. 3rdly, its telescopic power is usually far higher than that of a sextant, and is always much more effective, the instrument being held steadily on a stand instead of loosely by hand. 4thly, it may be so manipulated as to eliminate the effects—without ascertaining the magnitudes—of constant instrumental errors, such as eccentricity, collimation, and index errors. And 5thly, the influence of graduation errors may, when great accuracy is required, be reduced to a very considerable extent by systematic changes of the zero settings of the horizontal circle.

The disadvantages of the altazimuth instrument as compared with the sextant are its greater cost and bulk and weight; but in many instances these disadvantages will be more than counterbalanced by its superior capabilities.

The following table gives the relative cost, weight, telescopic power, and precision of graduation of Messrs. Troughton and Simms' instruments of both classes.

Instrument.	Weight of with Box.	Weight of Stand	Price.			Telescopic Powers.	Readings of Verniers.	Details.
	lbs.	lbs.	£	s.	d.			
7-inch (radius) sextant	7½	..	12	0	0	5 to 10	10″	
Artificial horizon ..	5 to 10	..	3	5	0	..	..	
3-inch (diameter) transit theodolite	11	7½	22	10	0	14	1′	Without transit axis level, and lamp.
4-inch " "	18	10	29	0	0	10 to 16	1′	With transit axis level, and lamp.
5-inch " "	24	12	31	0	0	11 " 18	30″	Do.
6 inch " "	33½	12	40	0	0	13 " 20	10″	Do.

The Messrs. Casella construct certain very light and cheap altazimuth instruments, with 3-inch circles, power 5, weight with box 4 lbs., weight of stand 3½ lbs. divided to 1′, price under £20.

For astronomical observations the sextant is decidedly preferable to very small altazimuth instruments, but the latter are to be preferred for the measurement of horizontal angles and terrestrial elevations or depressions.

The traveller must necessarily adapt his equipment to his requirements, and to the facilities he will possess for carrying instruments about.

He may find it convenient to employ a sextant for astronomical, and a very small light altazimuth for terrestrial observations. But, whenever practicable, an altazimuth of moderate size, which may be used as a universal instrument, would undoubtedly be the most convenient and satisfactory.

Trigonometrical operations are, as a rule, far simpler and more easily reduced, and lead to more accurate results than astronomical observations. A continuous triangulation, or a traverse with measured angles and distances, is necessarily impossible when the explorer has to pass through a country very rapidly; but he may frequently remain for several days at one place, and may then have opportunities of greatly extending the scope of his operations by executing a triangulation. Suppose him to be in view of a range of hills which he may not have an opportunity of exploring, distant say 50 to 100 miles; he may have already endeavoured on his line of march to fix points on the range by bearings, but from the absence of prominent landmarks has found a difficulty in identifying the points observed, and thinks he may have mistaken one hill for another in consequence of their changes in appearance as viewed from positions at some distance apart. If, during his few days' halt, he can manage to do a little triangulation, he may fix the general outlines of the entire range relatively to his halting-place with very respectable accuracy. He has first to measure a base and determine by triangulation the positions of three stations lying in a direction nearly parallel to that of the range, and at distances of 2 to 5 miles apart; then at each of these stations he must measure the angles between the other stations and a series of points on the entire length of the range.* Though no very prominent landmarks

* He should make a sketch of the outline of the range in his book of observations; and as he will probably be unable to ascertain the names of the hill summits at such a distance from them, and many of them may have no names, he had better number them in the order in which they are observed, and refer to them always by these numbers, until he can confidently replace a number by a name. Exaggerated sketches of the outlines of the objects intersected by the telescope are frequently of use to facilitate identification on proceeding to the next station.

The positions of places situated within or beyond the range of hills which are invisible to the traveller, but are known to his native guides and assistants, may

may be visible, still the telescope will show a number of objects—trees, masses of rock, and peculiarities of the ground—sufficiently clearly to permit of their being recognised and identified at stations of observation which are so close to each other: and though the triangles will be very acute-angled, the angles may easily be measured with sufficient accuracy to give the distances of the points on the ranges from the stations of observation with a small percentage of error, whenever the marks are truly identified; and as there will be two triangles to each point, and therefore, double values of the side common to both triangles, any mistakes—whether of identity, or of reading, or calculation—will be at once shown up.

Whenever a break of continuity occurs in the triangulation or traversing, astronomical observations must be resorted to. Much may be done by a judicious introduction of latitudes and azimuths, more particularly where there is considerable northing and southing, for then good differences of longitude may be obtained from the azimuths and differences of latitude. A prominent peak, visible from great distances all round, may be made to serve as a connecting link between regions which cannot be continuously connected, by measuring its azimuth and distance from a base-line in each region; the addition of latitudes, at the azimuth stations, strengthens the work.

The 6-inch subtense theodolite by Messrs. Troughton and Simms has been much used in explorations connected with the operations of the Great Trigonometrical Survey of India, and given great satisfaction, being sufficiently accurate for all desirable purposes, and not too heavy to be easily carried. It is adapted for determinations of time and longitude by the method of zenith distances, and also by that of meridional transits, the former being best suited for the traveller when he can only devote a few hours to the operations, the latter when he is halting for a long time at one place; the two methods lead to strictly independent results, so that when both are employed they serve to check each other. It is also well suited for latitude and azimuth observations; in fact, it can be

be approximately determined by making a native point the theodolite, as a gun, in the direction of the place and state the distance beyond or on this side of the range.

employed in any of the investigations which an explorer may have to undertake by means of astronomical observations.

It is specially provided with a pair of micrometers in the eye-piece of the telescope, for the purpose of measuring small angles, and more particularly those subtended by objects of known dimensions, by means of which the distance between the object and the observer is readily deduced. The system of micrometers is moveable through an angle of 90°, so as to permit of the measurement of either a horizontal or a vertical object. With the aid of this appliance, the instrument can be employed in carrying on a traverse without using any direct measuring apparatus, such as a chain or perambulator, the distances to the back and forward stations being determined by measuring the angles subtended by a pole of known length, or between two poles at a known distance. In hilly and broken ground in crossing rivers or other obstacles, and generally wherever a direct measurement is impracticable, this method of procedure is most convenient. With one of these instruments a traverse of the line of country passed over by the British army in the Abyssinian expedition, was carried from Adigerat to Magdala, a distance of nearly 300 miles, without any break of continuity, the daily rate of progress averaging 5 miles, and being occasionally as much as 8 miles. The difference of latitude between the origin and terminus as determined from these operations only differed by about a quarter of a mile from the value determined astronomically. Whenever a halt occurred in the movements of the army, the instrument was used as a theodolite in triangulating, to fix the positions of all hills and other prominent objects around the halting-place; it was also used for various astronomical observations.*

* These instruments being furnished with a pair of micrometers, which can be used either horizontally or vertically, are all the more valuable for astronomical observations; for the micrometers give two additional wires over which the stars may be observed, and these wires can be set at pleasure to any distance from the fixed wires in the diaphragm which may be best suited to the rate of movement of the star. For pairs of observations—face right and face left—no reductions to the centre wire are necessary; and thus greater accuracy is obtained with very slight additional trouble of observing, and still less of computing.

Remarks on the Manipulation of Altazimuth Instruments.

Observations with these instruments should always be made in pairs, with the face of the vertical circle alternately to the right and left of the observer. Thus, supposing that in the first observation, or round of observations, the face of that circle is to the right of the observer, the telescope should be immediately afterwards moved through 180° in azimuth, and turned over in altitude, which will bring the face of the circle to the left of the observer, and then a second observation, or round of observations, should be taken; the mean of the two measures, face right and face left, will be free from collimation, index, and other instrumental errors.

In measuring horizontal angles between objects of nearly the same altitude, as landmarks not much above or below the horizon, a change of face is not absolutely necessary, and may be dispensed with if the observer is hurried; but when such angles are measured between objects of very different altitudes—as a terrestrial referring mark and a star—and whenever altitudes are measured, whether of terrestrial or celestial objects, the observations should invariably be taken in both positions, alternately "face right" and "face left," and the final result deduced from the mean, in order that the instrumental errors may be eliminated. There is no necessity to determine the magnitude of these errors, as in the sextant; in an instrument which has to travel far over bad ground the adjustments are liable to alter from time to time, but they are not likely to alter in the interval between two consecutive observations, and the errors arising therefrom will be eliminated in the mean of the pair.

In what follows regarding *astronomical* observations with these instruments, a complete observation will be understood to imply the mean of a pair of observations, one with face right, the other with face left, taken continuously without any considerable pause between them, the entire operation being considered as one observation.

Determinations of Time, Azimuth, Latitude and Longitude, with a Subtense Theodolite.

The subtense theodolite may be employed either as a transit instrument, or as an altazimuth instrument; it is adapted for all astronomical observations, excepting those of "lunar distances," which can only be performed by a sextant or a reflecting circle, and occultations, which require larger telescopes.

Thus a description of each of the various kinds of observations which can be made with transit and altazimuth instruments, with full details of the methods to be employed in the corresponding reductions, would fill a volume, and be much more than is required for a book which merely purports to give hints to travellers. Those who wish to learn full particulars of each of the several methods of observation, and of the reductions, cannot do better than study Chauvenet's 'Spherical and Practical Astronomy,' which is one of the most valuable works on the subject in the English language: it gives ample instructions for observations of all kinds, the rudest and most hurried, as well as the most refined and elaborate, and it supplies corresponding formulæ—approximate as well as rigorous—for the reduction of the observations.

As these Hints are merely intended to indicate the simplest and most expeditious methods by which a traveller who is able to carry a suitable altazimuth instrument about with him, can take the astronomical observations which are essentially necessary for his geographical explorations, they will be restricted to determinations of time, latitude and longitude by the measurement of zenith distances, and of azimuths by horizontal angles; formulæ—some approximate but all sufficiently rigorous for the purpose, and adapted mostly from Chauvenet—will also be given, for the reduction of the observations.

Latitude Observations, the time being unknown.—The instrument being duly levelled and brought approximately into the meridian, set the telescope on any star—or on the sun—when approaching culmination, and follow it until the maximum altitude is reached; take the zenith-distance reading on the vertical circle, change face quickly, and make a second observation; the mean of the two will be a "complete observation" of zenith distance. Two or three pairs of observations may be taken to

circumpolar stars, as their zenith distances will not alter sensibly during an interval of a quarter to half an hour; for other stars the observations should be restricted to one pair, and stars should not be observed when within 25° of the zenith. A single pair of observations with the 6-inch transit theodolite should give a determination within 20″ of the truth; greater accuracy may be obtained by observing additional stars, more particularly when the stars are selected so as to form pairs of nearly equal distance from the zenith, north and south.

Latitude Observations, the time being known.—(1.) Observe the zenith distance of the Pole-star in any position, and reduce to the meridian by the tables in the 'Nautical Almanac.'

(2.) Take circum-meridian observations of the zenith distance of any star, alternately face right and face left, and note the time of each observation; compute the reduction of the zenith distance at the time of observation to the distance on the meridian, and take the mean of the reduced results as the determination of the meridional zenith distance. Three or four pairs of observations may generally be made in succession to the same star; but the nearer the star is to the zenith the more accurately should the times be known—it is not desirable, therefore, to observe stars within 10° of the zenith. Here, too, pairs of north and south stars of nearly equal zenith distance will give the best results.

Time.—Take pairs of observations of the zenith distance of a star, noting the chronometer time of each, and adopt the mean of the times as the time corresponding to the mean zenith distance, with which, the latitude of the place, and the star's declination, the star's hour angle must be computed by either of the well-known formulæ: thus the local time and the chronometer error will be determined. For these observations stars are most favourably situated which are easterly or westerly, and not very near either to the horizon or to the meridian; and greatest accuracy is obtained when two stars are observed at nearly the same altitude, one to the east, the other to the west. With a pair of observations the chronometer error should be determined within 1 second when a 6-inch transit theodolite is used.

Longitude.—Take pairs of observations of zenith distance, face right and face left, on a star, for the determination of local time and chronometer error; then take other pairs of observations of zenith distance on the moon; in each instance adopt the mean of the chronometer times as

the time of the "complete observation" of zenith distance. Both moon and star should be as nearly easterly or westerly as possible, and always materially nearer the prime vertical than the meridian; and they should be sufficiently above the horizon to prevent the observations being sensibly affected by errors of refraction. The operations should commence and close with star observations, for time and chronometer rate. The effect of instrumental errors will probably be sensibly reduced when the star and the moon are on the same side of the meridian, and nearly at the same zenith distance. If time permits, observations should be taken both east and west of the meridian; and both before and after full moon.

The best time for observing the moon is when the direction of the resultant of her motion in right ascension and declination is pointing towards the zenith of the observer.

The sidereal time when this occurs may be readily found, graphically, by drawing on a chart of the heavens a tangent to the moon's orbit, at some point near its mean position on any given day, and producing the tangent to cut the declination circle passing through the observer's zenith; then the hour circle passing through the point of intersection gives the sidereal time of observation. It will ordinarily suffice to drop a perpendicular from the point indicating the moon's position on the ecliptic, and draw through that point a line at right angles with the perpendicular to cut the declination circle. It will be found that the most favourable time occurs when the moon is near the prime vertical, and the least favourable when she is near the meridian. In north latitudes the moon is most favourably situated when west of the meridian if her motion in declination is from south to north, and when east of the meridian if the motion in declination is from north to south.

A few observations taken daily on several days are preferable to several observations on a single day.

Azimuth, time and latitude being unknown.—Observe the angles between a referring mark* and a star, when the star is at the same altitude east

* A good referring mark may be made of a cross with a hole of $\frac{1}{4}$ to $\frac{1}{2}$ an inch in diameter in the centre, to which observations can be taken by day and by night, being rendered visible at night by a bull's-eye lantern placed behind the hole and directed to the observer. The stem of the cross should be vertical, and

and west of the meridian; several pairs of observations may be taken at consecutive altitudes, half with face right and half with face left. Or the angles may be measured between a referring mark and a circumpolar star at the times of its maximum elongations east and west. The mean of the two angles at opposite positions gives the angle between the star and the meridian, and thence the azimuth of the referring mark, without any calculations whatever. In the first case, however, an interval of several hours must be allowed to elapse between the observations east and west; and as twelve hours must necessarily elapse between the opposite elongations of a circumpolar star, few stars will ordinarily be visible at both elongations.

It may therefore be desirable to adopt a third and more expeditious method, as follows:—Measure the angles between the referring mark and *two* circumpolar stars at their respective elongations, selecting stars which are nearly in opposition or nearly in conjunction, and will attain their maximum elongations at nearly the same time, that the observations may be completed quickly; then, with the observed value of the angle between the stars, and the given declinations of the stars, the azimuths of both may be readily computed, as shown at page 255.

Azimuths, latitude being known.—Observe the angle between the referring mark and a circumpolar star at maximum elongation, and compute the azimuth of the star. To stars near the pole two or three pairs of observations, face left and face right, may be taken before the star moves sensibly from the position of maximum elongation.

Azimuth, latitude and time being known.—Any star may be observed in any position, but the best results will be obtained when a circumpolar star is observed at a short distance from the elongation; the angle between the position of the star at the observation and at the elongation may be computed by the last formula at page 255.

Azimuth, latitude and star's altitude being known.—Observe the angle between the referring mark and an east or west star, and measure the vertical angle of the star simultaneously by observing the star at the

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driven firmly into the ground. The distance from the station of observation should be at least half a mile, and the station should be marked by a pin driven into the ground, over which the theodolite must be carefully centered whenever set up for horizontal observations.

intersection of the horizontal and vertical wires of the theodolite; change face and repeat the measures of the horizontal and vertical angles, taking the mean of each as a "complete observation." The star should not be at a high altitude; it should be situated near the prime vertical, and rather on the side towards the apparent pole than on the opposite side.

This method is extensively practised in the Indian Surveys for the determination of verificatory azimuths for revenue surveys, for which it has been found more convenient than any other method. The observations are usually taken between sunset and dark, when there is sufficient light to dispense with lamps for illuminating the wires of the telescope or indicating the referring mark; a lamp to illuminate the graduations of the circles is, however, generally necessary.

General Remarks.—The observed zenith distances should always be corrected for refraction; barometer and thermometer readings should, therefore, be taken during the observations, for the better determination of the refraction. When no barometer is at hand, the height of the station of observation should be given, as deduced by the boiling point or otherwise, or even approximately estimated. It may be well to remember, in determining latitude by observing pairs of north and south stars of the same zenith distance, that the means are uninfluenced by refraction, and therefore corrections for refraction may be dispensed with.

Formulæ and Examples.

Latitude by Circum-meridian Observations of a Star.

Let ϕ be the true latitude, ζ the true zenith distance on the meridian, ζ_0 the observed zenith distance corrected for refraction, δ the declination of the star,* ϕ_0 an approximate value of ϕ, $= \delta \pm \zeta_0$, t the hour angle of the star.

$$\text{Put } A = \frac{\cos\phi_0 \cos\delta}{\sin\zeta_0} \text{ and } m = \frac{2}{\sin 1''}\sin^2 \tfrac{1}{2}t.$$

$$\text{Then } \zeta = \zeta_0 - A\,m, \text{ and } \phi = \delta \pm \zeta.$$

* When the sun is observed, the declination corresponding to the mean of the times of observation should be used.

The values of m are given in table X. (p. 280).

Alternative forms of m, adapted for various logarithmic tables.

$$\left.\begin{aligned} m &= \text{cosec } 1'' \text{ versin } t. \\ &= \cdot 00055 t^2, \text{ when } t \text{ is given in seconds of time,} \\ &= 2\, t^2 \text{ nearly, } \quad ,, \qquad ,, \quad \text{minutes} \quad ,, \end{aligned}\right.$$

Supposing n observations to be taken, then, since A is constant,

$$\zeta = \zeta_0 - \mathrm{A}\frac{m_1 + m_2 + \ldots + m_n}{n}.$$

Example.—Circum-meridian Observations for Latitude to β Ursæ Minoris North of the Zenith.

Face.	Circle Readings.*	°	′	″	Mean Zenith Distances of Pairs of Observations. °	′	″	Chronometer. H.	M.	S.	t. in Minutes of Time.	t^2.
Left	Alt.	54	10	20	35	47	38	14	45	47	7·2	52
Right	Z. D.	35	45	35					47	1	6·0	36
,,	,,	35	45	0	35	47	5		48	55	4·1	17
Left	Alt.	54	10	50					51	30	1·5	2
,,	,,	54	11	0	35	47	8		54	37	1·6	3
Right	Z. D.	35	45	15					56	22	3·4	12
,,	,,	35	45	30	35	47	25		57	43	4·7	22
Left	Alt.	54	10	40					58	48	5·6	31
,,	,,	54	10	30	35	47	40	15	0	18	7·3	53
Right	Z. D.	35	45	50					2	10	9·2	85
	Mean				35	47	23				Mean ..	31·3
	Refraction ..					+	42					
	ζ_0 =				35	48	5				$31 \cdot 3 \times 2 = 62 \cdot 6$.	
	$-\mathrm{A}m$ =					−	21					
	ζ =				35	47	44	$\phi = 38° 58' 53''$ N.				

Data.			
	H.	M.	S.
Æ of Star ..	14	51	14
Chron. Error	+	1	46
Chron. Time of Transit	14	53	0
	°	′	″
δ .. .. =	74	46	37
ζ_0 .. .. =	35	48	5
ϕ_0	38	58	32
log cos ϕ_0			9·8906
log cos δ			9·4192
log cosec ζ_0 ..			0·2328
log A			9·5426
log 62·6			1·7965
log Am			1·3391

For the above formula t should be less than 20 minutes, and ζ greater than 10°.

* The circle readings will be alternately altitudes and zenith distances ± the index error of the instrument, which error is eliminated in the mean of a pair of observations

Longitude by Lunar Zenith Distances.

The local time and the chronometer error having been determined from the star observations.

Let ζ_0 = the observed zenith distance of the moon's limb.
Θ = the local sidereal time of the observation of ζ_0.
L_1 = an assumed value of the longitude.
ΔL_1 = the required correction of L_1.
L = the true longitude $= L_1 + \Delta L_1$.
ϕ = the latitude.

Find the Greenwich time corresponding to Θ and L_1, for which take

$$\left.\begin{array}{l}\delta = \text{the moon's declination.}\\ \pi = \text{the moon's equatorial horizontal parallax.}\\ S = \text{the moon's geocentric semi-diameter.}\end{array}\right\} \begin{array}{c}\text{from the}\\ \text{'Naut. Alm.'}\end{array}$$

Let S_1 be the moon's apparent semi-diameter, and π_1 the corrected parallax,

$$\text{then } S_1 = S + \Delta S, \text{ and } \pi_1 = \pi + \Delta \pi;$$

and the values of ΔS and $\Delta \pi$ may be interpolated from the following tables which are abridged from Chauvenet.

Also put $\delta_1 = \delta + e^2 \pi_1 \sin \phi \cos \delta$, in which $\log e^2 = 7{\cdot}8244$; and let r be the refraction for the apparent zen. dis. ζ_0;

$$\text{and let } \zeta_2 = \zeta_0 + r \pm S_1,$$
$$\text{and } \zeta_1 = \zeta_2 - \pi_1 \sin \zeta_2;$$

then the hour angle, t, is found from the equation

$$\sin^2 \tfrac{1}{2} t = \frac{\sin \frac{1}{2} [\zeta_1 + (\phi - \delta_1)] \sin \frac{1}{2} [\zeta_1 - (\phi - \delta_1)]}{\cos \phi \cos \delta_1},$$

after which the moon's right ascension, Æ, is found by the formula

$$Æ = \Theta - t.$$

Apparent Zen. Dis. of Moon.	Values of Δ S, always +.						Value of Δ π, always +.			
	Horizontal Semi-diameter.						Latitude.	Equatorial Parallax.		
	′ ″ 14 30	′ ″ 15 0	′ ″ 15 30	′ ″ 16 0	′ ″ 16 30	′ ″ 17 0		′ 53	′ 57	′ 61
°	″	″	″	″	″	″	°	″	″	″
0	13·7	14·6	15·6	16·7	17·7	18·8	0	0·0	0·0	0·0
10	13·5	14·4	15·4	16·4	17·5	18·6	10	0·3	0·3	0·4
20	12·9	13·8	14·7	15·7	16·7	17·7	20	1·2	1·3	1·4
30	11·8	12·7	13·5	14·4	15·4	16·3	30	2·7	2·9	3·1
40	10·5	11·2	12·0	12·8	13·6	14·4	40	4·4	4·7	5·1
50	8·8	9·4	10·1	10·7	11·4	12·1	50	6·2	6·7	7·2
60	6·9	7·3	7·9	8·4	8·9	9·5	60	8·0	8·6	9·2
70	4·7	5·1	5·4	5·8	6·1	6·5	70	9·4	10·1	10·8
80	2·4	2·6	2·8	3·0	3·2	3·4	80	10·3	11·1	11·9
90	0·1	0·1	0·1	0·1	0·2	0·2	90	10·6	11·4	12·2

The Greenwich mean time corresponding to the moon's Æ must be found from the 'Nautical Almanac'; with this and the local mean time a value of the longitude is determined, which, however, is approximate only, as t, is computed with an approximate value of δ depending on the assumed longitude. Put L_2 for the approximate value of the longitude which is thus determined, and

put β = the increase of δ in a unit of time, and λ = ,, Æ ,, $\Big\{$ at the Greenwich mean time of the observation of the moon;

$$\text{also let } a = \frac{\beta}{15\,\lambda}\left\{\frac{\tan\phi}{\sin t} - \frac{\tan\delta}{\tan t}\right\};$$

$$\text{then } \Delta L_1 = \frac{L_2 - L_1}{1 + a}, \text{ and } L = L_1 + \Delta L_1.$$

These formulæ are demonstrated in Chauvenet, vol. i. pages 383 to 385; and when several observations have to be reduced, they entail less labour of computation than any other formula.

Example.—In latitude $\phi = 38° 58' 53''$ N. and assumed longitude $L_1 =$ 5 h. 6 m. west of Greenwich, on May 2nd, 1849, the moon being east of the meridian, the zenith distance of the moon's upper limb was observed to be 57° 47′ 28·5″, when the local mean time was 5 h. 33 m. 21·6 s., and the local sidereal time Θ = 8 h. 16 m. 14·61 s.

Approximate Greenwich mean time, 10 h. 39 m. 21·6 s. for which we find from the 'N.A.'

$$\delta = +3°47'47{\cdot}6''$$
$$S = 15\ 16{\cdot}4$$
$$\pi = 56\ 3{\cdot}1$$

Bar. 30·45 in., Att. Therm. 63° F., Ext. ,, 65° F.

$$\begin{array}{lrrr} & ° & ' & '' \\ \zeta_0 = & 57 & 47 & 28{\cdot}5 \\ r = & + & 1 & 30{\cdot}9 \\ S_1 = & + & 15 & 24{\cdot}5 \\ \hline \zeta_2 = & 58 & 4 & 23{\cdot}9 \\ -\pi_1 \sin \zeta_2 = & - & 47 & 38{\cdot}1 \\ \hline \zeta_1 = & 57 & 16 & 45{\cdot}8 \\ \hline \delta_1 = & 3 & 48 & 1{\cdot}7 \end{array}$$

and from the tables on page we find

$$\Delta S = +\ 8{\cdot}1$$
$$\Delta \pi = +\ 4{\cdot}4$$
$$\frac{e^2 \pi_1 \sin \phi}{\cos \delta} = +\ 14{\cdot}1$$

With these values of δ_1, ζ_1, and ϕ we find—

$$\begin{array}{rrrr} & \text{H.} & \text{M.} & \text{S.} \\ t = & -3 & 19 & 53{\cdot}64; \\ \text{but } \Theta = & 8 & 16 & 14{\cdot}61; \\ \text{whence the computed Æ} = & 11 & 36 & 8{\cdot}25. \end{array}$$

	H.	M.	S.
The corresponding Greenwich mean time for this value of the Æ is	10	39	48·7
The local mean time is	5	33	21·6
Whence the approx. long L_2 is	5	6	27·1

For the Greenwich mean time 10 H. 39 M. 48·7 S. { increase of Æ in 1 M. = 2·014 S. = λ. ; ,, δ ,, 10·01″ = β.

Whence a = − 0·3317 : and since $L_2 - L_1$ = + 27·1 s.,

ΔL_1 = 40·6 S., and L = 5 H. 6 M. 40·6 S.

Formulæ for the reduction of Azimuth Observations.

(1) When a star is observed at an elongation.
Let A be the azimuth, δ the declination, ϕ the latitude.

$$\text{Then } \sin A = \frac{\cos \delta}{\cos \phi}.$$

(2) When a star is observed at a short distance from the elongation.
Let t be the hour angle at the time of elongation,

$$\text{then } \cos t = \frac{\tan \phi}{\tan \delta}.$$

Let $d\,t$ be the difference between the hour angles at the times of elongation and of observation, and d A the corresponding difference of azimuth,

$$\text{then } \tan \mathrm{d}\,A = -\,2 \sin^2 \frac{d\,t}{2} \sec \phi \cot \delta \operatorname{cosec} t;$$

whence if $d\,t$ is expressed *in minutes of time*, and κ is a constant,

$$\log \kappa \text{ being } = \cdot 29303 + \log \sec \phi + \log \cot \delta + \log \operatorname{cosec} t,$$

$$\mathrm{d}\,A'' = -\,\kappa\,(d\,t)^2.$$

(3) When two stars are observed at their elongations.
Let their azimuths be A_1 and A_2, and their declinations δ_1 and δ_2,

$$\text{then } \sin A_1 = \frac{\cos \delta_1}{\cos \delta_2} \sin A_2.$$

The value of $A_1 + A_2$ or of $A_1 - A_2$ is given by the observations, $A_1 + A_2$ if the stars are at opposite elongations, $A_1 - A_2$ if they are at the same elongation. Suppose that we have

$$A_1 \pm A_2 = m$$

$$\text{then } \cot A_1 = \cot m \pm \frac{\cos \delta_2}{\cos \delta_1} \operatorname{cosec} m,$$

$$\text{or } \cot A_2 = \cot m \pm \frac{\cos \delta_1}{\cos \delta_2} \operatorname{cosec} m.$$

Explanation of the Tables.

Table I. contains the sun's declination, to the nearest minute, for the years 1893-94–95 and '96; the declinations for the years 1897–98-99 and 1900, and are almost equally correct.

Table II. contains the equation of time for 1893–94-95 and '96 to the nearest second, and will serve very well for common purposes for the 4th or 8th years after. The error will be greatest from the latter end of May to the middle of July, to 2 secs. or 3 secs. in a period of four years. The words "add" or "sub." indicate the manner in which the equation is to be applied to *apparent time* to convert it into mean time.

Table III. contains the sun's mean right ascension. The months are given at the top of the table, the days in the side column. It will be found useful for ascertaining the *approximate* time of an object's meridian passage, but where accuracy is necessary recourse must be had to the 'Nautical Almanac.'

To find the approximate time of a star passing the meridian, subtract the sun's right ascension from the star's right ascension (increasing the star's right ascension by 24 hours if it is less than the sun's right ascension), and the remainder will be the approximate time of the star passing the meridian.

Table IV. contains the mean places of 50 stars of the first and second magnitudes for the 1st of January, 1894, with their annual variation in right ascension and declination.

Tables V. and VI.—Table V. contains the approximate times of the meridian passages of 50 of the principal stars for the 1st of the month. To find the time of passage on any other day, *subtract* the portion of time corresponding to the day of the month in Table VI. from the time in Table V. As the times given in these tables are *apparent*, they must be converted into *mean* time by applying the equation of time as directed in Table II. should the mean time of meridian passage be required. The result arrived at by the use of these tables is only approximate, but will seldom be as much as 2m. in error.

N.B. The altitude of any star when passing the meridian may be found by adding together the complement of the latitude of the place of observation and the declination of the star, when they are of the same name,

or taking their difference when of contrary names; the altitude to be reckoned from the south point of the horizon when the latitude is north, and the contrary when south; but when the sum exceeds 90° it is to be taken from 180°, and the altitude is to be reckoned from the north in north latitude, and the south in south latitude. When using the artificial horizon, the altitude to which the index of the sextant is to be set must, of course, be *double the altitude* found by this method.

Table VII. contains the refraction for the barometer at 30 inches, and Fahrenheit's thermometer at 50°. The two small tables at the side contain corrections when the barometer differs from 30 inches or the thermometer from 50°.

Table VIII. exhibits half the time that a celestial body continues above the horizon when the latitude and declination are the same name; or below it when they are contrary names, and affords the means for computing the rising and setting of the sun, moon and stars, and the length of the night or day.

To find the time of the sun's rising or setting, enter Table VIII. with the latitude and declination, and the tabular value will show the apparent time of the sun's setting when the latitude and declination are the same name, or of its rising when the latitude and declination are of contrary names, and this, subtracted from 12 hours, will give the apparent time of the sun's rising in the former case, and of its setting in the latter.

Double the time of rising will give the length of the night.

Double the time of setting will give the length of the day.

Example.—Required the (apparent) time of the sun's rising and setting, and the length of the day and night in lat. 46° N., and the declination 18° N.

Tabular value answering to lat. 46° and decl. 18° is 7 h. 19 m. Hence in lat. 46° N., decl. 18° N., time of sunset is 7 h. 19 m., and that of sunrise 12 h. − 7 h. 19 m. = 4 h. 41 m.

The same is true for lat. 46° S., decl. 18° S.

Conversely, both for lat. 46° N., decl. 18° S., and for lat. 46° S., decl. 18° N., the time of sunrise is 7 h. 19 m., and that of sunset is 4 h. 41 m.

In the first pair of cases the length of the day is 7 h. 19 m. × 2 = 14 h. 38 m., and that of the night is 4 h. 41 m. × 2 = 9 h. 22 m.; and in the second pair, conversely, the length of the night is 14 h. 38 m., and that of the day 9 h. 22 m.

To find the time of a star's rising and setting, subtract the sun's right ascension, Table III., from the star's right ascension, Table IV. (increasing the star's right ascension by 24 hours if it is less than the sun's right ascension), and the remainder will be the approximate time of the star's passing the meridian; then the latitude and declination found in this table will give the time the star takes in ascending from the horizon to the meridian, and descending from the meridian to the horizon, when the latitude and declination are the same names; therefore, if these hours and minutes be subtracted from the time of its passage over the meridian, the remainder will be the apparent time of its rising; and, if added, the sum will be the time of its setting.

When the latitude and declination are of contrary names, the time found in the table will be the half of the continuance of the star below the horizon; consequently it is to be subtracted from 12 hours to give half the time of its continuance above the horizon.

Example.—At what time (apparent) does the star *β Leonis* rise and set on May 30th in lat. 46° N.?

	H. M.
Star's R. A.	11 43
Sun's R. A.	4 27
Star's approximate meridian passage	7 16
Time in table answering to lat 46° N. and star's declination 15° 15′ N...	7 4
Remainder = time of star's rising	00 12
Sum = time of star's setting	14 20 P.M.
or	2 20 A.M.

Example.—At what time (apparent) does the star *a Ophiuchi* rise and set on May 12th, in lat. 30 S.?

	H. M.
Star's R. A.	17 29
Sun's R. A.	3 15
Star's approximate meridian passage	14 14
Time answering in table to 30° s. lat., and star's declination 12° 39′ N. = 6 h. 30 m. which, subtracted from 12, gives 5 h. 30 m.	5 30
Remainder = time of star's rising	8 44
Sum = time of star's setting	19 44 P.M.
or	7 44 A.M.

Table IX., giving the distance of the horizon as seen over water from different heights above it, will be found very useful both in checking exaggerated estimates of the width of lakes whose opposite shores are invisible, and also as a rude means of judging the distance of objects seen across water.

Table X. gives the values of $\frac{2 \sin^2 \text{half-hour angle}}{\sin 1''}$, and is used in finding the latitude by altitudes of the sun, or of stars when they are near the meridian.

Table XI. gives the number of geographical miles, or minutes of the equator, contained in a degree of longitude under each parallel of latitude on the supposition of the earth's spheroidal shape with a compression of $\frac{1}{304}$.

Table XII. is for converting statute into geographical miles.

Table XIII. is for converting geographical into statute miles.

Table XIV. contains a comparison of Fahrenheit, Réaumur, and Centigrade thermometer scales.

Table XV. contains a comparison of English and French barometer scales to hundredths of an inch.

Table XVI. contains a comparison of mètres and English feet.

Table XVII. contains a comparison of kilomètres and English statute miles.

Table XVIII. contains a comparison of Russian versts and English statute miles.

Table XIX. contains a comparison of kilogrammes and pounds, avoirdupois.

Table XX. contains foreign moneys, with equivalents in British currency.

Table XXI. contains the difference of latitude and departure for the course at each degree. It will also be found useful for the conversion of one measure of length into another, thus: at 61°, the dist. and dep. correspond to statute and geographical miles; at 77°, dist. and dep. correspond to English and Danish feet; at 68°, dist. and dep. correspond to Dutch and English feet; at 66°, dist. and dep. correspond to French mètres and English yards; at 70°, dist. and dep. correspond to toises and fathoms; at 25°, dist. and dep. correspond to English feet and arsheens; at 35°, dist. and dep. correspond to versts and geographical miles; at 66°, dist. and dep. correspond to brazas and fathoms, or to varas and yards. These tables can also be used in solving, approximately, cases of right-angled triangles, as also in verifying the results of questions of the kind when obtained by logarithms.

Table XXII. contains natural sines, cosines, tangents, cotangents, secants, and cosecants for each degree.

Table XXIII. is used to facilitate finding the longitude by moon culminating stars; for the manner in which it is used, see p. 233.

Table XXIV. This table contains the angles subtended by a 10 ft. rod, at distances from 50 to 1500 feet. The angles are given for every foot from 50 to 200 feet, for every two feet from 200 to 402 feet, and for every yard from 402 to 1500 feet. To use the table, search column for the angle measured, and opposite to this will be found the distance in feet. In that part of the table, where the distances are only given for every second or third foot, intermediate distances can be found by interpolation.

Table XXV. contains useful constants.

Tables XXVI. and XXVII. contain the times occupied in the transmission of letters and parcels by post from London to certain places abroad.

Table I.—Declination of the Sun for the Years 1893 and 1897 at Mean Noon at Greenwich.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '
1	22 58 S.	16 57 S.	7 23 S.	4 44 N.	15 14 N.	22 8 N.	23 6 N.	17 55 N.	8 7 N.	3 23 S.	14 36 S.	21 54 S.
2	22 53	16 40	7 0	5 8	15 32	22 16	23 1	17 39	7 45	3 46	14 55	22 3
3	22 47	16 22	6 37	5 30	15 49	22 23	22 56	17 24	7 23	4 9	15 14	22 11
4	22 40	16 4	6 14	5 53	16 7	22 30	22 51	17 8	7 1	4 32	15 33	22 19
5	22 34	15 46	5 51	6 16	16 24	22 37	22 45	16 52	6 39	4 56	15 51	22 27
6	22 26	15 27	5 28	6 39	16 41	22 43	22 39	16 35	6 16	5 19	16 9	22 34
7	22 19	15 8	5 4	7 1	16 57	22 49	22 33	16 18	5 54	5 42	16 27	22 41
8	22 11	14 49	4 41	7 24	17 14	22 54	22 26	16 1	5 31	6 5	16 44	22 47
9	22 2	14 30	4 17	7 46	17 30	22 59	22 19	15 44	5 8	6 28	17 1	22 53
10	21 53	14 11	3 54	8 8	17 45	23 4	22 12	15 26	4 46	6 50	17 18	22 59
11	21 44	13 51	3 30	8 30	18 1	23 8	22 4	15 9	4 23	7 13	17 35	23 3
12	21 34	13 31	3 7	8 52	18 16	23 12	21 55	14 51	4 0	7 36	17 51	23 8
13	21 24	13 11	2 43	9 14	18 31	23 15	21 47	14 32	3 37	7 58	18 7	23 12
14	21 13	12 50	2 19	9 36	18 45	23 18	21 37	14 14	3 14	8 20	18 23	23 16
15	21 2	12 30	1 56	9 57	18 59	23 21	21 28	13 55	2 51	8 43	18 38	23 19
16	20 50	12 9	1 32	10 18	19 13	23 23	21 18	13 36	2 27	9 5	18 53	23 21
17	20 38	11 48	1 8	10 39	19 27	23 24	21 8	13 17	2 4	9 27	19 8	23 23
18	20 26	11 27	0 45	11 0	19 40	23 26	20 58	12 57	1 41	9 49	19 22	23 25
19	20 14	11 5	0 21 S.	11 21	19 53	23 27	20 47	12 38	1 18	10 10	19 36	23 26
20	20 1	10 44	0 3 N.	11 42	20 5	23 27	20 35	12 18	0 54	10 32	19 50	23 27
21	19 47	10 22	0 27	12 2	20 18	23 27	20 24	11 58	0 31	10 53	20 3	23 27
22	19 33	10 0	0 50	12 22	20 29	23 27	20 12	11 38	0 8 N.	11 14	20 16	23 27
23	19 19	9 38	1 14	12 42	20 41	23 26	20 0	11 18	0 16 S.	11 35	20 28	23 26
24	19 5	9 16	1 37	13 2	20 52	23 25	19 47	10 57	0 39	11 56	20 40	23 25
25	18 50	8 53	2 1	13 21	21 3	23 24	19 34	10 36	1 3	12 17	20 52	23 24
26	18 35	8 31	2 25	13 41	21 13	23 22	19 21	10 15	1 26	12 38	21 3	23 22
27	18 19	8 8	2 48	14 0	21 23	23 19	19 7	9 54	1 49	12 58	21 14	23 19
28	18 3	7 46	3 11	14 19	21 33	23 16	18 53	9 33	2 13	13 18	21 25	23 16
29	17 47	..	3 35	14 37	21 42	23 13	18 39	9 12	2 36	13 38	21 35	23 13
30	17 31	..	3 58	14 56	21 51	23 10	18 25	8 50	2 59	13 58	21 45	23 9
31	17 14	..	4 21	..	22 0	..	18 10	8 29	..	14 17	..	23 4

TABLE I. (*continued*).—DECLINATION OF THE SUN FOR THE YEARS 1894 AND 1898 AT MEAN NOON AT GREENWICH.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	22 59S.	17 1S.	7 29S.	4 39N.	15 10N.	22 6N.	23 7N.	17 58N.	8 12N.	3 17S.	14 32S.	21 52S
2	22 54	16 44	7 6	5 2	15 27	22 14	23 2	17 43	7 50	3 41	14 51	22 1
3	22 48	16 26	6 43	5 25	15 45	22 21	22 58	17 27	7 28	4 4	15 10	22 9
4	22 42	16 8	6 20	5 48	16 3	22 28	22 52	17 12	7 6	4 27	15 28	22 18
5	22 35	15 50	5 57	6 11	16 20	22 35	22 47	16 55	6 44	4 50	15 47	22 25
6	22 28	15 32	5 33	6 33	16 37	22 41	22 41	16 39	6 21	5 13	16 5	22 33
7	22 21	15 13	5 10	6 56	16 53	22 47	22 35	16 22	5 59	5 36	16 22	22 39
8	22 13	14 54	4 47	7 18	17 10	22 53	22 28	16 5	5 36	5 59	16 40	22 46
9	22 4	14 35	4 23	7 41	17 26	22 57	22 21	15 48	5 14	6 22	16 57	22 52
10	21 55	14 15	4 0	8 3	17 42	23 3	22 13	15 30	4 51	6 45	17 14	22 57
11	21 46	13 56	3 36	8 25	17 57	23 7	22 5	15 13	4 28	7 8	17 31	23 2
12	21 36	13 36	3 12	8 47	18 12	23 11	21 57	14 55	4 5	7 30	17 47	23 7
13	21 26	13 15	2 49	9 9	18 27	23 14	21 49	14 37	3 42	7 53	18 3	23 11
14	21 15	12 55	2 25	9 30	18 42	23 17	21 40	14 18	3 19	8 15	18 19	23 15
15	21 5	12 35	2 1	9 52	18 56	23 20	21 30	13 59	2 56	8 37	18 34	23 18
16	20 53	12 14	1 38	10 13	19 10	23 22	21 21	13 40	2 33	8 59	18 49	23 21
17	20 41	11 53	1 14	10 34	19 24	23 24	21 10	13 21	2 10	9 21	19 4	23 23
18	20 29	11 32	0 50	10 55	19 37	23 26	21 0	13 2	1 46	9 43	19 18	23 25
19	20 17	11 10	0 27	11 16	19 50	23 27	20 49	12 43	1 23	10 5	19 33	23 26
20	20 4	10 49	0 3S.	11 37	20 2	23 27	20 38	12 23	1 0	10 27	19 46	23 27
21	19 50	10 27	0 21N.	11 57	20 15	23 27	20 27	12 3	0 36	10 48	20 0	23 27
22	19 37	10 5	0 44	12 17	20 26	23 27	20 15	11 43	0 13N.	11 9	20 13	23 27
23	19 23	9 43	1 8	12 37	20 38	23 26	20 3	11 22	0 10S.	11 30	20 25	23 27
24	19 8	9 21	1 32	12 57	20 49	23 25	19 50	11 2	0 34	11 51	20 37	23 26
25	18 54	8 59	1 55	13 17	21 0	23 24	19 37	10 41	0 57	12 12	20 49	23 24
26	18 39	8 37	2 19	13 36	21 11	23 22	19 24	10 20	1 21	12 33	21 1	23 22
27	18 23	8 14	2 42	13 55	21 21	23 20	19 11	9 59	1 44	12 53	21 12	23 20
28	18 7	7 51	3 6	14 14	21 31	23 17	18 57	9 38	2 7	13 13	21 22	23 17
29	17 51	..	3 29	14 33	21 40	23 14	18 43	9 17	2 31	13 33	21 33	23 13
30	17 35	..	3 52	14 51	21 49	23 10	18 28	8 55	2 54	13 53	21 42	23 10
31	17 18	..	4 16	..	21 58	..	18 13	8 34	..	14 13	..	23 5

TABLE I. (*continued*).—DECLINATION OF THE SUN FOR THE YEARS 1895 AND 1899 AT MEAN NOON AT GREENWICH.

Day	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	23 1S.	17 5S.	7 34S.	4 33N.	15 5N.	22 4N.	23 8N.	18 2N.	8 17N.	3 12S.	14 27S.	21 50S.
2	22 55	16 48	7 11	4 56	15 23	22 12	23 3	17 47	7 55	3 35	14 46	21 59
3	22 50	16 30	6 48	5 19	15 41	22 19	22 59	17 31	7 33	3 58	15 5	22 7
4	22 44	16 13	6 25	5 42	15 59	22 27	22 54	17 15	7 11	4 21	15 24	22 16
5	22 37	15 54	6 2	6 5	16 16	22 33	22 48	16 59	6 49	4 45	15 42	22 23
6	22 30	15 36	5 39	6 28	16 33	22 40	22 42	16 43	6 27	5 8	16 0	22 31
7	22 22	15 17	5 16	6 50	16 49	22 46	22 36	16 26	6 4	5 31	16 18	22 38
8	22 15	14 59	4 52	7 13	17 6	22 51	22 30	16 9	5 42	5 54	16 36	22 44
9	22 6	14 39	4 29	7 35	17 22	22 57	22 23	15 52	5 19	6 17	16 53	22 50
10	21 57	14 20	4 5	7 58	17 38	23 1	22 15	15 35	4 56	6 39	17 10	22 56
11	21 48	14 0	3 42	8 20	17 53	23 6	22 7	15 17	4 34	7 2	17 27	23 1
12	21 39	13 41	3 18	8 42	18 9	23 10	21 59	14 59	4 11	7 25	17 43	23 6
13	21 29	13 20	2 55	9 3	18 24	23 13	21 50	14 41	3 48	7 47	17 59	23 10
14	21 18	13 0	2 31	9 25	18 38	23 17	21 42	14 23	3 25	8 10	18 15	23 14
15	21 7	12 40	2 7	9 47	18 53	23 19	21 33	14 4	3 2	8 32	18 31	23 17
16	20 56	12 19	1 44	10 8	19 7	23 22	21 23	13 45	2 39	8 54	18 46	23 20
17	20 44	11 58	1 20	10 29	19 20	23 24	21 13	13 26	2 15	9 16	19 1	23 22
18	20 32	11 37	0 56	10 50	19 34	23 25	21 3	13 7	1 52	9 38	19 15	23 24
19	20 20	11 16	0 32	11 11	19 47	23 26	20 52	12 47	1 29	10 0	19 29	23 26
20	20 7	10 54	0 9S.	11 32	19 59	23 27	20 41	12 28	1 5	10 22	19 43	23 27
21	19 54	10 32	0 15N.	11 52	20 12	23 27	20 29	12 8	0 42	10 43	19 56	23 27
22	19 40	10 11	0 39	12 12	20 24	23 27	20 18	11 48	0 19N.	11 4	20 9	23 27
23	19 26	9 49	1 2	12 32	20 35	23 27	20 6	11 27	0 5S.	11 25	20 22	23 27
24	19 12	9 27	1 26	12 52	20 47	23 26	19 53	11 7	0 28	11 46	20 34	23 26
25	18 57	9 4	1 50	13 12	20 58	23 24	19 40	10 46	0 52	12 7	20 46	23 25
26	18 42	8 42	2 13	13 31	21 8	23 23	19 27	10 25	1 15	12 28	20 58	23 23
27	18 27	8 19	2 37	13 51	21 18	23 20	19 14	10 4	1 38	12 48	21 9	23 20
28	18 11	7 57	3 0	14 10	21 28	23 18	19 0	9 43	2 2	13 8	21 20	23 18
29	17 55	..	3 24	14 28	21 38	23 15	18 46	9 22	2 25	13 28	21 30	23 14
30	17 39	..	3 47	14 47	21 47	23 11	18 32	9 1	2 48	13 48	21 40	23 11
31	17 22	..	4 10	..	21 56	..	18 17	8 39	..	14 8	..	23 6

TABLE I. *(continued)*.—DECLINATION OF THE SUN FOR THE YEARS 1896 AND 1900 AT MEAN NOON AT GREENWICH.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	23 2 S.	17 9 S.	7 17 S.	4 51 N.	15 19 N.	22 10 N.	23 4 N.	17 51 N.	8 1 N.	3 29 S.	14 42 S.	21 57 S.
2	22 57	16 52	6 54	5 14	15 37	22 18	23 0	17 35	7 39	3 53	15 1	22 5
3	22 51	16 35	6 31	5 37	15 54	22 25	22 55	17 19	7 17	4 16	15 19	22 14
4	22 45	16 17	6 8	6 0	16 12	22 32	22 50	17 3	6 55	4 39	15 38	22 22
5	22 39	15 59	5 44	6 23	16 29	22 38	22 44	16 47	6 32	5 2	15 56	22 29
6	22 32	15 41	5 21	6 45	16 45	22 44	22 38	16 30	6 10	5 25	16 14	22 36
7	22 24	15 22	5 58	7 8	17 2	22 50	22 31	16 14	5 47	5 48	16 32	22 43
8	22 17	15 3	4 34	7 30	17 18	22 55	22 24	15 56	5 25	6 11	16 49	22 49
9	22 8	14 44	4 11	7 52	17 34	23 0	22 17	15 39	5 2	6 34	17 6	22 55
10	22 0	14 25	3 47	8 14	17 50	23 5	22 9	15 21	4 39	6 57	17 23	23 0
11	21 50	14 5	3 24	8 36	18 5	23 9	22 1	15 4	4 16	7 19	17 39	23 5
12	21 41	13 45	3 0	8 58	18 20	23 13	21 53	14 45	3 53	7 42	17 55	23 9
13	21 31	13 25	2 36	9 20	18 35	23 16	21 44	14 27	3 30	8 4	18 11	23 13
14	21 21	13 5	2 13	9 42	18 49	23 19	21 35	14 8	3 7	8 27	18 27	23 16
15	21 10	12 44	1 49	10 3	19 3	23 21	21 25	13 50	2 44	8 49	18 42	23 19
16	20 59	12 24	1 25	10 24	19 17	23 23	21 15	13 31	2 21	9 11	18 57	23 22
17	20 47	12 3	1 2	10 45	19 30	23 25	21 5	13 11	1 58	9 33	19 12	23 24
18	20 35	11 42	0 38	11 6	19 44	23 26	20 54	12 52	1 34	9 55	19 26	23 25
19	20 23	11 21	0 14 S.	11 27	19 56	23 27	20 43	12 32	1 11	10 16	19 40	23 26
20	20 10	10 59	0 10 N.	11 47	20 9	23 27	20 32	12 12	0 48	10 38	19 53	23 27
21	19 57	10 38	0 33	12 8	20 21	23 27	20 20	11 52	0 24	10 59	20 6	23 27
22	19 43	10 16	0 57	12 28	20 33	23 27	20 8	11 32	0 1 N.	11 20	20 19	23 27
23	19 29	9 54	1 20	12 48	20 44	23 26	19 56	11 12	0 22 S.	11 41	20 31	23 26
24	19 15	9 32	1 44	13 7	20 55	23 25	19 43	10 51	0 46	12 2	20 43	23 25
25	19 1	9 10	2 8	13 27	21 6	23 23	19 30	10 30	1 9	12 23	20 55	23 23
26	18 46	8 47	2 31	13 46	21 16	23 21	19 17	10 10	1 33	12 43	21 6	23 21
27	18 30	8 25	2 55	14 5	21 26	23 18	19 3	9 48	1 56	13 4	21 17	23 18
28	18 15	8 2	3 18	14 24	21 35	23 15	18 49	9 27	2 19	13 24	21 28	23 15
29	17 59	7 39	3 41	14 43	21 45	23 12	18 35	9 6	2 43	13 43	21 38	23 12
30	17 43	..	4 5	15 1	21 53	23 8	18 21	8 44	3 6	14 3	21 47	23 7
31	17 26	..	4 28	..	22 2	..	18 6	8 23	..	14 22	..	23 3

TABLE II.—EQUATION OF TIME FOR THE YEAR 1893 FOR APPARENT NOON AT GREENWICH.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
	Add	Add	Add	Add	Sub.	Sub.	Add	Add	Sub.	Sub.	Sub.	Sub.
1	4 0	13 52	12 26	3 48	3 4	2 23	3 37	6 4	0 14	10 28	16 20	10 40
2	4 28	13 59	12 14	3 30	3 11	2 14	3 49	6 0	0 33	10 47	16 21	10 17
3	4 56	14 5	12 1	3 12	3 18	2 4	3 60	5 55	0 53	11 6	16 21	9 53
4	5 23	14 11	11 47	2 55	3 23	1 54	4 10	5 50	1 12	11 24	16 20	9 29
5	5 50	14 15	11 34	2 37	3 29	1 44	4 21	5 44	1 32	11 42	16 18	9 4
6	6 16	14 19	11 19	2 20	3 34	1 33	4 31	5 38	1 52	11 59	16 15	8 38
7	6 42	14 22	11 5	2 2	3 38	1 22	4 41	5 31	2 12	12 16	16 12	8 12
8	7 7	14 24	10 50	1 46	3 42	1 11	4 50	5 23	2 33	12 33	16 7	7 45
9	7 32	14 26	10 34	1 29	3 45	0 59	4 59	5 15	2 53	12 49	16 2	7 18
10	7 56	14 26	10 19	1 12	3 47	0 47	5 8	5 6	3 14	13 5	15 56	6 51
11	8 20	14 26	10 3	0 56	3 49	0 35	5 16	4 57	3 35	13 20	15 49	6 23
12	8 43	14 26	9 47	0 41	3 50	0 23	5 23	4 47	3 56	13 35	15 41	5 55
13	9 5	14 24	9 30	0 20	3 51	0 10 Add	5 31	4 36	4 17	13 49	15 32	5 26
14	9 27	14 22	9 13	0 10 Sub.	3 51	0 3	5 38	4 25	4 38	14 2	15 23	4 58
15	9 48	14 19	8 56	0 5	3 51	0 16	5 44	4 14	4 59	14 16	15 13	4 28
16	10 9	14 15	8 39	0 19	3 50	0 29	5 50	4 2	5 20	14 28	15 1	3 59
17	10 29	14 10	8 22	0 33	3 48	0 42	5 55	3 49	5 41	14 40	14 49	3 30
18	10 48	14 5	8 4	0 47	3 46	0 55	6 0	3 36	6 2	14 52	14 37	3 0
19	11 6	13 59	7 46	1 0	3 43	1 8	6 4	3 23	6 24	15 2	14 23	2 30
20	11 24	13 53	7 28	1 13	3 40	1 21	6 7	3 8	6 45	15 13	14 9	2 0
21	11 41	13 46	7 10	1 25	3 36	1 34	6 10	2 54	7 6	15 22	13 54	1 31
22	11 57	13 38	6 52	1 37	3 32	1 47	6 13	2 39	7 27	15 31	13 38	1 1
23	12 12	13 29	6 34	1 49	3 27	1 59	6 15	2 23	7 48	15 39	13 21	0 31
24	12 26	13 20	6 15	2 0	3 22	2 12	6 16	2 7	8 9	15 47	13 3	0 1 Add
25	12 40	13 10	5 57	2 10	3 16	2 25	6 17	1 51	8 29	15 54	12 45	0 29
26	12 53	13 0	5 39	2 21	3 10	2 37	6 17	1 34	8 50	16 0	12 26	0 58
27	13 5	12 50	5 20	2 30	3 3	2 50	6 16	1 17	9 10	16 5	12 6	1 28
28	13 16	12 38	5 2	2 39	2 56	3 3	6 15	0 59	9 30	16 20	11 46	1 57
29	13 26	..	4 43	2 48	2 48	3 14	6 13	0 41	9 50	16 14	11 25	2 26
30	13 36	..	4 25	2 56	2 40	3 26	6 11	0 23	10 9	16 17	11 3	2 55
31	13 44	..	4 7	..	2 32	..	6 8	0 5	..	16 19	..	3 24

TABLE II. (*continued*).—EQUATION OF TIME FOR THE YEAR 1894 FOR APPARENT NOON AT GREENWICH.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug	Sept.	Oct.	Nov.	Dec.
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
	Add	Add	Add	Add	Sub.	Sub.	Add	Add	Sub.	Sub.	Sub.	Sub.
1	3 53	13 50	12 28	3 52	3 3	2 25	3 36	6 7	0 8	10 22	16 19	10 45
2	4 21	13 57	12 16	3 34	3 10	2 16	3 47	6 3	0 27	10 41	16 19	10 22
3	4 49	14 4	12 3	3 16	3 16	2 6	3 58	5 59	0 46	10 59	16 19	9 58
4	5 16	14 9	11 50	2 58	3 22	1 56	4 9	5 54	1 5	11 18	16 19	9 34
5	5 43	14 14	11 37	2 41	3 28	1 45	4 20	5 48	1 25	11 36	16 17	9 9
6	6 10	14 18	11 23	2 24	3 32	1 34	4 30	5 42	1 45	11 53	16 15	8 44
7	6 36	14 22	11 8	2 7	3 37	1 23	4 40	5 35	2 5	12 10	16 11	8 18
8	7 1	14 24	10 53	1 50	3 40	1 12	4 50	5 27	2 26	12 27	16 7	7 51
9	7 26	14 26	10 38	1 33	3 43	1 0	4 59	5 19	2 46	12 43	16 2	7 25
10	7 51	14 27	10 23	1 17	3 46	0 49	5 7	5 10	3 7	12 59	15 57	6 58
11	8 15	14 27	10 7	1 0	3 48	0 37	5 16	5 1	3 28	13 15	15 50	6 30
12	8 38	14 26	9 51	0 45	3 49	0 24	5 23	4 51	3 49	13 30	15 43	6 2
13	9 1	14 25	9 34	0 29	3 50	0 12 Add	5 31	4 41	4 10	13 44	15 34	5 34
14	9 23	14 22	9 17	0 14 Sub.	3 51	0 1	5 37	4 30	4 31	13 58	15 25	5 5
15	9 44	14 20	9 0	0 1	3 50	0 13	5 44	4 18	4 53	14 12	15 15	4 36
16	10 4	14 16	8 43	0 16	3 50	0 26	5 50	4 6	5 14	14 25	15 4	4 7
17	10 24	14 11	8 26	0 30	3 48	0 39	5 55	3 53	5 35	14 37	14 53	3 38
18	10 43	14 6	8 8	0 44	3 47	0 52	6 0	3 40	5 56	14 49	14 40	3 8
19	11 2	14 0	7 50	0 57	3 44	1 5	6 4	3 27	6 18	15 0	14 27	2 39
20	11 19	13 54	7 32	1 10	3 41	1 18	6 7	3 13	6 39	15 10	14 13	2 9
21	11 36	13 47	7 14	1 23	3 38	1 31	6 10	2 58	7 0	15 20	13 58	1 39
22	11 52	13 39	6 56	1 35	3 34	1 43	6 13	2 43	7 21	15 29	13 42	1 9
23	12 8	13 30	6 37	1 47	3 29	1 56	6 15	2 28	7 42	15 37	13 25	0 39
24	12 22	13 21	6 19	1 58	3 24	2 9	6 16	2 12	8 3	15 45	13 8	0 9 Add
25	12 36	13 12	6 0	2 9	3 18	2 22	6 17	1 56	8 23	15 52	12 49	0 21
26	12 49	13 2	5 42	2 19	3 12	2 35	6 17	1 39	8 43	15 58	12 30	0 51
27	13 1	12 51	5 23	2 29	3 5	2 47	6 17	1 22	9 4	16 3	12 11	1 21
28	13 12	12 40	5 5	2 38	2 58	3 0	6 16	1 5	9 24	16 8	11 50	1 50
29	13 23	..	5 47	2 47	2 51	3 12	6 15	0 47	9 43	16 12	11 29	2 20
30	13 33	..	4 28	2 55	2 43	3 24	6 13	0 29	10 3	16 15	11 7	2 49
31	13 42	..	4 10	..	2 34	..	6 10	0 11	..	16 17	..	3 18

TABLE II. (*continued*).—EQUATION OF TIME FOR THE YEAR 1895 FOR APPARENT NOON AT GREENWICH.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
	Add	Add	Add	Add	Sub.	Sub.	Add	Add	Sub.	Sub.	Sub.	Sub.
1	3 46	13 48	12 32	3 57	3 0	2 27	3 33	6 8	0 3	10 17	16 19	10 50
2	4 15	13 56	12 19	3 39	3 8	2 18	3 45	6 4	0 22	10 36	16 20	10 28
3	4 43	14 2	12 7	3 21	3 14	2 8	3 56	6 0	0 42	10 55	16 20	10 4
4	5 10	14 8	11 54	3 3	3 20	1 58	4 7	5 55	1 1	11 14	16 20	9 40
5	5 37	14 13	11 40	2 45	3 26	1 48	4 17	5 49	1 21	11 32	16 18	9 16
6	6 3	14 17	11 26	2 28	3 31	1 37	4 27	5 43	1 41	11 50	16 16	8 50
7	6 30	14 21	11 12	2 11	3 36	1 27	4 37	5 36	2 1	12 7	16 13	8 25
8	6 55	14 23	10 57	1 54	3 40	1 15	4 47	5 28	2 22	12 24	16 9	7 59
9	7 20	14 25	10 42	1 37	3 43	1 4	4 56	5 20	2 42	12 40	16 4	7 32
10	7 44	14 26	10 26	1 20	3 46	0 52	5 4	5 12	3 3	12 56	15 59	7 5
11	8 8	14 26	10 10	1 4	3 48	0 40	5 13	5 2	3 24	13 12	15 52	6 37
12	8 32	14 26	9 54	0 48	3 50	0 28	5 21	4 53	3 45	13 27	15 45	6 9
13	8 54	14 24	9 38	0 32	3 51	0 16	5 28	4 42	4 6	13 41	15 37	5 41
14	9 16	14 22	9 21	0 17	3 52	0 3	5 35	4 32	4 27	13 55	15 28	5 12
						Add						
15	9 38	14 19	9 4	0 2	3 51	0 9	5 41	4 20	4 48	14 9	15 18	4 43
				Sub.								
16	9 58	14 16	8 46	0 13	3 51	0 22	5 47	4 9	5 9	14 22	15 7	4 14
17	10 18	14 12	8 29	0 27	3 50	0 35	5 53	3 56	5 30	14 34	14 55	3 44
18	10 38	14 7	8 11	0 41	3 48	0 48	5 58	3 43	5 51	14 46	14 43	3 15
19	10 56	14 1	7 54	0 55	3 45	1 1	6 2	3 30	6 12	14 57	14 30	2 45
20	11 14	13 55	7 36	1 8	3 42	1 14	6 6	3 16	6 33	15 7	14 15	2 15
21	11 31	13 48	7 18	1 20	3 39	1 27	6 10	3 2	6 54	15 17	14 1	1 45
22	11 48	13 41	7 0	1 33	3 35	1 40	6 13	2 47	7 15	15 26	13 45	1 15
23	12 4	13 33	6 41	1 44	3 30	1 53	6 15	2 32	7 36	15 34	13 28	0 45
24	12 18	13 24	6 23	1 55	3 25	2 7	6 17	2 16	7 57	15 42	13 11	0 15
												Add
25	12 33	13 15	6 5	2 6	3 19	2 19	6 18	2 0	8 18	15 49	12 53	0 15
26	12 46	13 5	5 47	2 16	3 13	2 32	6 18	1 44	8 38	15 55	12 34	0 45
27	12 58	12 54	5 28	2 26	3 6	2 45	6 18	1 27	8 58	16 1	12 15	1 14
28	13 10	12 43	5 10	2 36	2 59	2 57	6 17	1 10	9 18	16 6	11 55	1 44
29	13 21	..	4 52	2 44	2 52	3 9	6 16	0 52	9 38	16 11	11 34	2 13
30	13 31	..	4 33	2 53	2 44	3 21	6 14	0 34	9 58	16 14	11 13	2 42
31	13 40	..	4 15	..	2 35	..	6 11	0 16	..	16 17	..	3 11

TABLE II. (*continued*).—EQUATION OF TIME FOR THE YEAR 1896 FOR APPARENT NOON AT GREENWICH.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
	Add	Add	Add	Add	Sub.	Sub.	Add	Add	Sub.	Sub.	Sub.	Sub.
1	3 40	13 47	12 23	3 44	3 6	2 20	3 41	6 4	0 19	10 33	16 20	10 34
2	4 8	13 54	12 11	3 26	3 12	2 11	3 52	5 59	0 38	10 52	16 20	10 10
3	4 36	14 1	11 56	3 8	3 19	2 1	4 3	5 54	0 57	11 10	16 20	9 46
4	5 3	14 7	11 44	2 50	3 25	1 51	4 14	5 49	1 17	11 28	16 19	9 21
5	5 30	14 12	11 30	2 33	3 30	1 40	4 24	5 43	1 37	11 46	16 17	8 56
6	5 57	14 17	11 16	2 15	3 34	1 29	4 34	5 36	1 57	12 3	16 14	8 30
7	6 23	14 20	11 1	1 58	3 38	1 18	4 44	5 29	2 17	12 20	16 10	8 4
8	6 49	14 23	10 46	1 42	3 42	1 7	4 53	5 22	2 37	12 36	16 5	7 38
9	7 14	14 25	10 31	1 25	3 45	0 55	5 2	5 13	2 58	12 52	16 0	7 10
10	7 39	14 27	10 15	1 9	3 47	0 43	5 11	5 4	3 19	13 8	15 53	6 43
11	8 3	14 27	9 59	0 53	3 49	0 31	5 19	4 55	3 40	13 23	15 46	6 15
12	8 26	14 27	9 43	0 37	3 50	0 18	5 26	4 45	4 1	13 38	15 38	5 47
13	8 49	14 26	9 26	0 22	3 50	0 6	5 33	4 34	4 22	13 52	15 29	5 18
						Add						
14	9 12	14 24	9 9	0 7	3 50	0 7	5 40	4 23	4 43	14 5	15 20	4 50
				Sub.								
15	9 34	14 22	8 52	0 8	3 49	0 20	5 46	4 11	5 4	14 18	15 9	4 20
16	9 55	14 18	8 35	0 22	3 48	0 33	5 52	3 59	5 25	14 31	14 58	3 51
17	10 15	14 14	8 18	0 36	3 47	0 46	5 57	3 46	5 46	14 43	14 46	3 22
18	10 35	14 10	8 0	0 50	3 44	0 59	6 1	3 33	6 8	14 54	14 33	2 52
19	10 53	14 4	7 42	1 3	3 41	1 12	6 5	3 19	6 29	15 5	14 19	2 22
20	11 12	13 58	7 24	1 15	3 38	1 25	6 9	3 5	6 50	15 15	14 5	1 53
21	11 29	13 52	7 6	1 28	3 34	1 38	6 12	2 50	7 11	15 24	13 49	1 23
22	11 45	13 44	6 48	1 40	3 30	1 50	6 14	2 35	7 32	15 33	13 33	0 53
23	12 1	13 36	6 29	1 51	3 25	2 3	6 15	2 19	7 53	15 41	13 16	0 23
												Add
24	12 16	13 27	6 11	2 2	3 20	2 16	6 16	2 3	8 14	15 49	12 58	0 7
25	12 30	13 18	5 53	2 13	3 14	2 29	6 17	1 47	8 34	15 55	12 40	0 37
26	12 44	13 8	5 34	2 23	3 8	2 41	6 17	1 30	8 55	16 1	12 21	1 6
27	12 56	12 58	5 15	2 32	3 1	2 53	6 16	1 12	9 15	16 6	12 1	1 36
28	13 8	12 47	4 57	2 42	2 54	3 5	6 15	0 55	9 35	16 11	11 40	2 5
29	13 19	12 35	4 39	2 50	2 46	3 18	6 13	0 37	9 54	16 14	11 19	2 35
30	13 29	..	4 20	2 58	2 38	3 29	6 10	0 19	10 14	16 17	10 56	3 4
								Sub.				
31	13 38	..	4 2	..	2 29	..	6 7	0 0	..	16 19	..	3 32

Table III.—Sun's Mean Right Ascension.

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
1	18 46	20 58	22 48	0 42	2 33	4 35	6 40	8 45	10 41	12 29	14 25	16 29
2	18 50	21 02	22 52	0 45	2 37	4 40	6 44	8 49	10 44	12 32	14 29	16 33
3	18 54	21 06	22 56	0 49	2 40	4 44	6 48	8 52	10 48	12 36	14 33	16 37
4	18 59	21 10	22 59	0 53	2 44	4 48	6 52	8 56	10 52	12 40	14 37	16 42
5	19 3	21 14	23 03	0 56	2 48	4 52	6 56	9 00	10 55	12 43	14 41	16 46
6	19 8	21 18	23 07	1 00	2 52	4 56	7 00	9 04	10 59	12 47	14 45	16 51
7	19 12	21 22	23 10	1 04	2 56	5 00	7 04	9 08	11 02	12 51	14 49	16 55
8	19 16	21 26	23 14	1 07	3 00	5 04	7 09	9 12	11 06	12 54	14 53	16 59
9	19 21	21 30	23 18	1 11	3 04	5 08	7 13	9 15	11 10	12 58	14 57	17 04
10	19 25	21 34	23 21	1 15	3 08	5 13	7 17	9 19	11 13	13 02	15 01	17 08
11	19 29	21 38	23 25	1 18	3 11	5 17	7 21	9 23	11 17	13 05	15 05	17 13
12	19 34	21 42	23 29	1 22	3 15	5 21	7 25	9 27	11 20	13 09	15 09	17 17
13	19 38	21 46	23 33	1 26	3 19	5 25	7 29	9 31	11 24	13 13	15 13	17 21
14	19 42	21 50	23 36	1 29	3 23	5 29	7 33	9 34	11 28	13 16	15 17	17 26
15	19 47	21 54	23 40	1 33	3 27	5 33	7 37	9 38	11 31	13 20	15 21	17 30
16	19 51	21 58	23 43	1 37	3 31	5 37	7 41	9 42	11 35	13 24	15 25	17 35
17	19 55	22 02	23 47	1 40	3 35	5 42	7 45	9 46	11 38	13 28	15 30	17 39
18	20 00	22 05	23 51	1 44	3 39	5 46	7 49	9 49	11 42	13 31	15 34	17 43
19	20 04	22 09	23 54	1 48	3 43	5 50	7 53	9 53	11 46	13 35	15 38	17 48
20	20 08	22 13	23 58	1 51	3 47	5 54	7 57	9 57	11 49	13 39	15 42	17 52
21	20 12	22 17	0 02	1 55	3 51	5 58	8 01	10 00	11 53	13 43	15 46	17 57
22	20 17	22 21	0 05	1 59	3 55	6 02	8 05	10 04	11 56	13 46	15 50	18 01
23	20 21	22 25	0 09	2 03	3 59	6 07	8 09	10 08	12 00	13 50	15 55	18 06
24	20 25	22 28	0 13	2 06	4 03	6 11	8 13	10 12	12 04	13 54	15 59	18 10
25	20 29	22 32	0 16	2 10	4 07	6 15	8 17	10 15	12 07	13 58	16 03	18 15
26	20 33	22 36	0 20	2 14	4 11	6 19	8 21	10 19	12 11	14 02	16 07	18 19
27	20 37	22 40	0 23	2 18	4 15	6 23	8 25	10 23	12 14	14 06	16 12	18 23
28	20 42	22 43	0 27	2 21	4 19	6 27	8 29	10 26	12 18	14 09	16 16	18 28
29	20 46	22 46	0 31	2 25	4 23	6 31	8 33	10 30	12 22	14 13	16 20	18 32
30	20 50	..	0 34	2 29	4 27	6 36	8 37	10 33	12 25	14 17	16 25	18 37
31	20 54	..	0 38	..	4 31	..	8 41	10 37	..	14 21	..	18 41

TABLE IV.—*MEAN PLACES OF 50 OF THE PRINCIPAL FIXED STARS FOR JANUARY 1ST, 1891.

Name.	Mag.	Right Asc.	Ann. Var.	Declination.	Ann. Var.
		h. m. s.	s.	° ′ ″	″
α Andromedæ	2	0 2 54·45	+3·09	+28 30 18·72	+19·90
γ Pegasi (*Algenib*)	3, 2	0 7 46·57	3·08	+14 35 38·77	20·03
α Phœnicis	2	0 21 2·53	2·97	−42 52 55·20	19·55
α Cassiopeiæ (var.)	2, 3	0 34 29·44	3·37	+55 57 20·86	19·79
β Ceti	2	0 38 16·09	3·01	−18 34 6·94	19·81
α Ursæ Minoris (*Polaris*)	2	1 20 4·50	24·12	+88 44 33·83	18·84
α Eridani (*Achernar*)	1	1 33 45·93	2·24	−57 46 32·31	18·33
α Arietis	2	2 1 11·79	3·37	+22 57 39·46	17·18
α Persei	2	3 16 45·19	4·26	+49 28 59·95	13·07
α Tauri (*Aldebaran*)..	1	4 29 50·22	3·44	+16 17 44·97	7·50
α Aurigæ (*Capella*)..	1	5 8 51·42	4·43	+45 53 22·82	4·01
β Orionis (*Rigel*)	1	5 9 26·58	2·88	− 8 19 28·07	4·39
β Tauri	2	5 19 35·42	3·79	+28 31 2·89	3·34
δ Orionis	2	5 26 35·39	3·06	−0 22 40·73	2·91
α Columbæ	2	5 35 48·69	2·18	−34 7 50·75	2·08
α Orionis (var.)	1	5 49 25·95	3·25	+7 23 12·70	0·95
α Argûs (*Canopus*)	1	6 21 35·84	1·33	−52 38 16·30	−1·89
α Canis Majoris (*Sirius*)	1	6 40 28·53	2·64	−16 34 18·14	4.73
ε Canis Majoris	2, 1	6 54 27·55	2·36	−28 49 41·32	4·71
δ Canis Majoris	2	7 4 4·87	2·44	−26 13 30·48	5·54
α^2 Geminorum (*Castor*)	2, 1	7 27 50·21	3·84	+32 7 14·38	7·58
α Canis Minoris (*Procyon*)	1	7 33 45·12	3·14	+5 29 47·65	9·01
β Geminorum (*Pollux*)	1, 2	7 38 49·77	3·68	+28 16 54·73	8·44
ι Argûs	2	9 14 15·22	1·61	−58 49 5[illegible]·16	15·04
α Hydræ	2	9 22 22·68	2·95	−8 11 57·73	15·44

* These Mean Places are not to be used for finding time.

TABLE IV. (*continued*).—*MEAN PLACES OF 50 OF THE PRINCIPAL FIXED STARS FOR JANUARY 1ST, 1894.

Name.	Mag.	Right Asc.	Ann. Var.	Declination.	Ann. Var.
		h. m. s.		° ′ ″	″
α Leonis (*Regulus*)	1,2	10 2 43·60	+3·19	+12 29 6·07	−17·47
η Argûs (var.)	1-6	10 40 56·95	2·32	−59 7 38·17	18·87
α Ursæ Majoris	2	10 57 11·10	3·74	+62 19 23·12	19·39
β Leonis	2	11 43 39·16	3·06	+15 9 52·20	20·10
γ Ursæ Majoris	2,3	11 48 15·31	3·17	+54 17 2·83	20·02
α[1] Crucis	1	12 20 42·21	3·29	−62 30 41·75	20·00
α Virginis (*Spica*)	1	13 19 36·43	3·15	−10 36 28·91	18·87
η Ursæ Majoris	2	13 43 21·85	2·37	+49 50 32·45	18·06
β Centauri	1	13 56 20·57	4·18	−59 51 41·38	17·57
α Boötis (*Arcturus*)	1	14 10 49·55	2·73	+19 44 3·80	18·185
α[2] Centauri	1	14 32 24·66	4·03	−60 23 42·68	15·04
β Libræ	2	15 11 18·10	3·22	−8 59 30·05	13·48
α Coronæ Borealis (*Alphecca*).. ..	2	15 30 11·96	2·54	+27 4 17·04	12·29
β[1] Scorpii	2	15 59 16·33	3·48	−19 30 54·36	10·11
α Scorpii (*Antares*)	1,2	16 22 54·39	3·67	−26 11 47·27	8·27
α Trianguli Australis	2	16 37 26·48	6·30	−68 49 56·71	7·12
β Aræ	3	17 16 29·40	4·98	−55 25 44·69	3·82
α Ophiuchi	2	17 30 0·79	2·78	+12 38 14·24	2·83
α Lyræ (*Vega*)	1	18 33 20·93	2·03	+38 41 6·37	+3·20
σ Sagittarii	2,3	18 48 41·47	3·72	−26 25 40·76	4·18
α Aquilæ (*Altair*)	1,2	19 45 36·65	2·93	+8 35 18·11	9·30
α Pavonis	2	20 17 15·71	4·78	−57 4 27·18	11·21
α Gruis..	2	22 1 33·07	3·80	−47 28 26·22	17·29
α Piscis Australis (*Fomalhaut*) ..	1,2	22 51 47·56	3·33	−30 11 3·05	19·01
α Pegasi (*Markab*)	2	22 59 28·80	2·98	+14 38 5·47	19·33

* These Mean Places are not to be used for finding time.

TABLE V.—APPROXIMATE TIMES OF THE MERIDIAN PASSAGES (*in apparent time*) OF 50 STARS OF THE 1ST AND 2ND MAGNITUDES ON THE FIRST DAY OF EACH MONTH.

Mag.	Stars.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
2	α Andromedæ	5 14	3 2	1 13	23 19	21 28	19 25	17 21	15 16	13 20	11 32	9 36	7 32
2,3	γ Pegasi .. (*Algenib*)	5 19	3 7	1 18	23 24	21 33	19 30	17 26	15 21	13 25	11 37	9 41	7 37
2	α Phœnicis	5 34	3 22	1 33	23 39	21 48	19 45	17 41	15 36	13 40	11 52	9 54	7 [illegible]
3	α Cassiopeiæ	5 46	3 33	1 44	23 51	21 59	19 57	17 52	15 48	13 52	12 4	10 7	8 4
2,3	β Ceti	5 50	3 37	1 48	23 55	23 3	20 1	17 56	15 52	13 55	12 7	10 11	8 7
2,3	α Ursæ Minoris .. (*Polaris*) ..	6 26	4 14	2 25	0 31	22 40	20 37	18 33	16 28	14 32	12 44	10 48	8 44
1	α Eridani .. (*Achernar*) ..	6 45	4 33	2 44	0 50	22 59	20 56	18 52	16 47	14 51	13 3	11 7	9 3
2,3	α Arietis	7 12	5 0	3 11	1 18	23 26	21 23	19 19	17 14	15 18	13 30	11 34	9 30
2,3	α Persei	8 28	6 16	4 26	2 33	0 42	22 39	20 34	18 30	16 34	14 46	12 49	10 46
1	α Tauri .. (*Aldebaran*)	9 41	7 29	5 40	3 46	1 55	23 52	21 48	19 43	17 47	15 59	14 3	11 59
1	α Aurigæ .. (*Capella*)	10 20	8 8	6 19	4 25	2 34	0 31	22 27	20 22	18 26	16 38	14 41	12 38
1	β Orionis .. (*Rigel*)	10 21	8 9	6 19	4 26	2 35	0 32	22 27	20 23	18 27	16 39	14 42	12 39
2	β Tauri	10 31	8 18	6 29	4 36	2 44	0 42	22 37	20 33	18 37	16 49	14 52	12 48
2	δ Orionis	10 39	8 27	6 38	4 44	2 53	0 50	22 46	20 41	18 45	16 57	14 59	12 55
3	α Columbæ	10 47	8 35	6 46	4 52	3 1	0 58	22 54	20 49	18 53	17 5	15 9	13 5
1	α Orionis .. (*Betelguese*) ..	11 1	8 48	6 59	5 6	3 14	1 12	23 7	21 3	19 7	17 19	15 22	13 18
1	α Argûs .. (*Canopus*)	11 33	9 21	7 32	5 38	3 47	1 44	23 40	21 35	19 39	17 51	15 55	13 51
1	α Canis Majoris .. (*Sirius*) ..	11 52	9 40	7 51	5 57	4 5	2 3	23 59	21 54	19 58	18 10	16 13	14 10
2	ε Canis Majoris	12 6	9 54	8 5	6 11	4 20	2 17	0 13	22 8	20 12	18 24	16 28	14 24
2	δ Canis Majoris	12 16	10 4	8 15	6 21	4 30	2 27	0 23	22 18	20 22	18 34	16 36	14 32
2	α^2 Geminorum .. (*Castor*) ..	12 39	10 27	8 38	6 44	4 53	2 50	0 46	22 41	20 45	18 57	17 1	14 57
1	α Canis Minoris .. (*Procyon*)	12 45	10 33	8 44	6 50	4 59	2 56	0 52	22 47	20 51	19 3	17 7	15 3
1,2	β Geminorum .. (*Pollux*) ..	12 50	10 38	8 49	6 55	5 4	3 1	0 57	22 52	20 56	19 8	17 12	15 8

2	ι Argûs	14 26	12 14	10 25	8 31	6 40	4 37	2 33	0 28	22 32	20 44	18 48	16 44
2	α Hydræ	14 34	12 21	10 32	8 39	6 47	4 45	2 40	0 36	22 40	20 52	18 55	16 51
1	α Leonis .. (*Regulus*)	15 14	13 2	11 13	9 19	7 28	5 25	3 21	1 16	23 21	21 32	19 36	17 32
1–6	η Argûs	15 52	13 40	11 51	9 58	8 6	6 3	3 59	1 54	23 58	22 10	20 14	18 10
1, 2	α Ursæ Majoris	16 8	13 56	12 7	10 13	8 22	6 19	4 15	2 10	0 14	22 26	20 30	18 26
3	β Leonis	16 55	14 43	12 54	11 0	9 9	7 6	5 2	2 57	1 1	23 13	21 17	19 13
2	γ Ursæ Majoris	16 59	14 47	12 58	11 5	9 13	7 10	5 6	3 1	1 5	23 17	21 21	19 17
1	α^1 Crucis	17 32	15 20	13 31	11 37	9 46	7 43	5 39	3 34	1 38	23 50	21 54	19 50
1	α Virginis .. (*Spica*)	18 31	16 19	14 30	12 36	10 45	8 42	6 38	4 33	2 37	0 49	22 52	20 49
2, 3	η Ursæ Majoris	18 55	16 43	14 54	13 0	11 9	9 6	7 2	4 57	3 1	1 13	23 16	21 13
1, 2	β Centauri	19 7	16 55	15 6	13 12	11 21	9 18	7 14	5 9	3 13	1 25	23 29	21 25
1	α Boötis .. (*Arcturus*)	19 22	17 10	15 21	13 27	11 36	9 33	7 29	5 24	3 28	1 40	23 44	21 40
1	α^2 Centauri	19 43	17 31	15 42	13 49	11 57	9 54	7 50	5 45	3 49	2 1	0 5	22 1
2	β Libræ..	20 22	18 10	16 21	14 27	12 36	10 33	8 29	6 24	4 28	2 40	0 42	22 38
2, 3	α Coronæ Borealis .. (*Alphecca*)	20 42	18 29	16 40	14 47	12 55	10 53	8 48	6 44	4 48	3 0	1 3	22 59
2	β^1 Scorpii	21 10	18 58	17 9	15 16	13 24	11 21	9 17	7 12	5 16	3 28	1 32	23 28
1	α Scorpii .. (*Antares*)	21 34	19 22	17 33	15 39	13 48	11 45	9 41	7 36	5 40	3 52	1 56	23 52
2	α Trianguli Australis	21 48	19 36	17 47	15 53	14 2	11 59	9 55	7 50	5 54	4 6	2 9	0 6
3	β Aræ	22 26	20 14	18 25	16 31	14 40	12 37	10 33	8 28	6 32	4 44	2 46	0 42
2, 3	α Ophiuchi	22 41	20 29	18 40	16 46	14 55	12 52	10 48	8 43	6 47	4 59	3 3	0 59
1	α Lyræ .. (*Vega*)	23 45	21 33	19 44	17 50	15 59	13 56	11 52	9 47	7 51	6 3	4 7	2 2
2, 3	σ Sagittarii	0 2	21 50	20 1	18 7	16 16	14 13	12 9	10 4	8 8	6 20	4 22	2 18
1, 2	α Aquilæ .. (*Altair*)	0 57	22 45	20 56	19 2	17 11	15 8	13 4	10 59	9 3	7 15	5 19	3 15
2	α Pavonis	1 28	23 16	21 27	19 33	17 42	15 39	13 35	11 30	9 34	7 46	5 50	3 46
1, 2	α Gruis..	3 13	1 0	23 11	21 18	19 26	17 24	15 19	13 15	11 19	9 31	7 34	5 30
1	α Piscis Australis.. (*Fomalhaut*)	4 3	1 51	0 2	22 8	20 17	18 14	16 10	14 5	12 9	10 21	8 25	6 21
2	α Pegasi .. (*Markab*)	4 11	1 59	0 10	22 16	20 25	18 22	16 18	14 13	12 17	10 29	8 32	6 29

TABLE VI.—CORRECTION FOR THE DAY OF THE MONTH, TO BE *subtracted* FROM THE APPARENT TIME OF A STAR'S MERIDIAN PASSAGE ON THE FIRST DAY OF THE MONTH.

Days.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2	0 4	0 4	0 4	0 4	0 4	0 4	0 4	0 4	0 4	0 4	0 4	0 4
3	0 9	0 8	0 7	0 7	0 8	0 8	0 8	0 8	0 7	0 7	0 8	0 9
4	0 13	0 12	0 11	0 11	0 11	0 12	0 12	0 12	0 11	0 11	0 12	0 13
5	0 18	0 16	0 15	0 15	0 15	0 16	0 16	0 15	0 14	0 15	0 16	0 17
6	0 22	0 20	0 19	0 18	0 19	0 21	0 21	0 19	0 18	0 18	0 20	0 22
7	0 26	0 24	0 22	0 22	0 23	0 25	0 25	0 23	0 22	0 22	0 24	0 26
8	0 30	0 28	0 26	0 26	0 27	0 29	0 29	0 27	0 25	0 25	0 28	0 30
9	0 35	0 32	0 30	0 29	0 30	0 33	0 33	0 31	0 29	0 29	0 32	0 35
10	0 39	0 36	0 33	0 33	0 35	0 37	0 37	0 35	0 32	0 33	0 36	0 39
11	0 43	0 40	0 37	0 36	0 39	0 41	0 41	0 38	0 36	0 37	0 40	0 44
12	0 48	0 44	0 41	0 40	0 42	0 45	0 45	0 42	0 40	0 40	0 44	0 48
13	0 52	0 48	0 44	0 44	0 46	0 49	0 49	0 46	0 43	0 44	0 48	0 52
14	0 56	0 52	0 48	0 48	0 50	0 54	0 53	0 50	0 47	0 48	0 52	0 57
15	1 1	0 56	0 52	0 51	0 54	0 58	0 57	0 53	0 50	0 51	0 56	1 1
16	1 5	1 0	0 55	0 55	0 58	1 2	1 1	0 57	0 54	0 55	1 0	1 6
17	1 9	1 3	0 59	0 59	1 2	1 6	1 5	1 1	0 58	0 59	1 4	1 10
18	1 13	1 7	1 2	1 2	1 6	1 10	1 9	1 5	1 1	1 3	1 9	1 15
19	1 18	1 11	1 6	1 6	1 10	1 14	1 13	1 8	1 5	1 6	1 13	1 19
20	1 22	1 15	1 10	1 10	1 14	1 19	1 17	1 12	1 8	1 10	1 17	1 24
21	1 26	1 19	1 14	1 13	1 18	1 23	1 21	1 16	1 12	1 14	1 21	1 28
22	1 31	1 23	1 17	1 17	1 22	1 27	1 25	1 19	1 16	1 18	1 25	1 32
23	1 35	1 26	1 21	1 21	1 26	1 31	1 29	1 23	1 19	1 21	1 30	1 37
24	1 39	1 30	1 24	1 25	1 30	1 35	1 33	1 27	1 23	1 25	1 34	1 41
25	1 43	1 34	1 28	1 28	1 34	1 39	1 37	1 31	1 26	1 29	1 38	1 46
26	1 47	1 38	1 32	1 32	1 38	1 44	1 41	1 34	1 30	1 33	1 42	1 50
27	1 51	1 42	1 35	1 36	1 42	1 48	1 45	1 38	1 34	1 37	1 47	1 55
28	1 56	1 45	1 39	1 40	1 46	1 52	1 49	1 42	1 37	1 41	1 51	1 59
29	2 0	..	1 43	1 44	1 50	1 56	1 53	1 45	1 41	1 44	1 55	2 3
30	2 4	..	1 46	1 47	1 55	2 0	1 57	1 49	1 44	1 48	1 59	2 8
31	2 8	..	1 50	..	1 59	..	2 1	1 52	..	1 52	..	2 12

Table VII.—Mean Astronomical Refraction.

(Barometer, 30 inches; Fahrenheit's Thermometer, 50°.)

App. Alt. ° ′	Refr. ′ ″	App. Alt. ° ′	Refr. ′ ″	App. Alt. ° ′	Refr. ′ ″	App. Alt. ° ′	Refr. ′ ″
0 00	34 17	4 00	11 47	6 55	7 30	10 00	5 20
0 10	32 15	4 05	11 36	7 00	7 25	10 10	5 15
0 20	30 23	4 10	11 26	7 05	7 20	10 20	5 10
0 30	28 41	4 15	11 15	7 10	7 16	10 30	5 06
0 40	27 07	4 20	11 05	7 15	7 11	10 40	5 01
0 50	25 41	4 25	10 55	7 20	7 07	10 50	4 56
1 00	24 22	4 30	10 46	7 25	7 03	11 00	4 52
1 10	23 09	4 35	10 37	7 30	6 59	11 10	4 48
1 20	22 02	4 40	10 28	7 35	6 54	11 20	4 44
1 30	21 00	4 45	10 19	7 40	6 50	11 30	4 40
1 40	20 02	4 50	10 10	7 45	6 46	11 40	4 36
1 50	19 09	4 55	10 02	7 50	6 42	11 50	4 32
2 00	18 20	5 00	9 54	7 55	6 38	12 00	4 28
2 10	17 34	5 05	9 46	8 00	6 35	12 10	4 25
2 15	17 12	5 10	9 38	8 05	6 31	12 20	4 21
2 20	16 51	5 15	9 30	8 10	6 27	12 30	4 18
2 25	16 31	5 20	9 23	8 15	6 23	12 40	4 14
2 30	16 11	5 25	9 16	8 20	6 20	12 50	4 11
2 35	15 52	5 30	9 09	8 25	6 16	13 00	4 08
2 40	15 34	5 35	9 02	8 30	6 13	13 10	4 05
2 45	15 16	5 40	8 55	8 35	6 09	13 20	4 02
2 50	14 59	5 45	8 48	8 40	6 06	13 30	3 59
2 55	14 42	5 50	8 42	8 45	6 03	13 40	3 56
3 00	14 26	5 55	8 36	8 50	6 00	13 50	3 53
3 05	14 10	6 00	8 30	8 55	5 57	14 00	3 50
3 10	13 55	6 05	8 24	9 00	5 54	14 10	3 47
3 15	13 41	6 10	8 18	9 05	5 51	14 20	3 45
3 20	13 27	6 15	8 12	9 10	5 48	14 30	3 42
3 25	13 13	6 20	8 06	9 15	5 45	14 40	3 40
3 30	13 00	6 25	8 01	9 20	5 42	14 50	3 37
3 35	12 47	6 30	7 56	9 25	5 39	15 00	3 35
3 40	12 34	6 35	7 50	9 30	5 36	15 10	3 32
3 45	12 22	6 40	7 45	9 35	5 33	15 20	3 30
3 50	12 10	6 45	7 40	9 40	5 31	15 30	3 28
3 55	11 58	6 50	7 35	9 50	5 25	15 40	3 25

TABLE VII.—MEAN ASTRONOMICAL REFRACTION.—*continued.*

(Barom. 30 inches; Therm. 50° Fahr.)

App. Alt.	Refr.	App. Alt.	Refr.	App. Alt.	Refr.
° ′	′ ″	° ′	′ ″	° ′	′ ″
15 50	3 23	31 00	1 37	57 00	0 37·9
16 00	3 21	31 30	1 35	58 00	0 36·5
16 10	3 19	32 00	1 33	59 00	0 35·1
16 20	3 17	32 30	1 31	60 00	0 33·7
16 30	3 15	33 00	1 30	61 00	0 32·4
16 40	3 13	33 30	1 28	62 00	0 31·0
16 50	3 11	34 00	1 26	63 00	0 29·8
17 00	3 09	34 30	1 25	64 00	0 28·5
17 30	3 03	35 00	1 23·2	65 00	0 27·2
18 00	2 58	35 30	1 21·7	66 00	0 26·0
18 30	2 53	36 00	1 20·2	67 00	0 24·8
19 00	2 48	36 30	1 18·8	68 00	0 23·6
19 30	2 44	37 00	1 17·4	69 00	0 22·4
20 00	2 39	37 30	1 16·0	70 00	0 21·3
20 30	2 35	38 00	1 14·6	71 00	0 20·1
21 00	2 31	38 30	1 13·3	72 00	0 19·0
21 30	2 27	39 00	1 12·0	73 00	0 17·9
22 00	2 24	39 30	1 10·7	74 00	0 16·7
22 30	2 20	40 00	1 09·5	75 00	0 15·7
23 00	2 17	41 00	1 07·1	76 00	0 14·6
23 30	2 13	42 00	1 04·8	77 00	0 13·5
24 00	2 10	43 00	1 02·6	78 00	0 12·4
24 30	2 07	44 00	1 00·4	79 00	0 11·3
25 00	2 05	45 00	0 58·4	80 00	0 10·3
25 30	2 02	46 00	0 56·3	81 00	0 09·2
26 00	1 59	47 00	0 54·4	82 00	0 08·2
26 30	1 56	48 00	0 52·6	83 00	0 07·2
27 00	1 54	49 00	0 50·7	84 00	0 06·1
27 30	1 51	50 00	0 49·0	85 00	0 05·1
28 00	1 49	51 00	0 47·3	86 00	0 04·1
28 30	1 47	52 00	0 45·6	87 00	0 03·1
29 00	1 45	53 00	0 44·0	88 00	0 02·0
29 30	1 43	54 00	0 42·4	89 00	0 01·0
30 00	1 41	55 00	0 40·9	90 00	0 00·0
30 30	1 39	56 00	0 39·4		

Corrections when Barom. differs from 30 inches or Therm. from 50° Fahr.

BAROMETER.

App. Alt.	For each inch above or below 30 inches:—*add*, if above 30; *subtract*, if below.
°	″
20	5
25	4
30	3
35	3
40	2
45	2
50	2
55	1
60	1
65	1
70	1

THERMOMETER.

App. Alt.	For each 10 degrees above or below 50° Fahr.:—*subtract*, if above 50°; *add*, if below.
°	″
20	3
25	3
30	2
35	2
40	1
45	1
50	1
55	1
60	1
65	1
70	0

TABLE VIII.—SEMI-DIURNAL AND SEMI-NOCTURNAL ARCHES, SHOWING THE TIME OF THE RISING AND SETTING OF THE SUN, MOON, OR EQUATORIAL STARS.

DECLINATION.

Lat.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	Lat.
°	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	°
1	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 1	6 1	6 1	6 1	6 1	6 1	1
2	6 0	6 0	6 0	6 0	6 1	6 1	6 1	6 1	6 1	6 1	6 1	6 2	6 2	6 2	2
3	6 0	6 0	6 0	6 1	6 1	6 1	6 1	6 1	6 2	6 2	6 2	6 2	6 3	6 3	3
4	6 0	6 0	6 1	6 1	6 1	6 1	6 2	6 2	6 2	6 3	6 3	6 3	6 3	6 4	4
5	6 0	6 0	6 1	6 1	6 1	6 2	6 2	6 2	6 3	6 3	6 4	6 4	6 4	6 5	5
6	6 0	6 0	6 1	6 1	6 2	6 2	6 3	6 3	6 3	6 4	6 4	6 5	6 5	6 6	6
7	6 0	6 0	6 1	6 1	6 2	6 2	6 3	6 3	6 4	6 4	6 5	6 5	6 6	6 6	7
8	6 0	6 1	6 1	6 2	6 2	6 3	6 3	6 4	6 5	6 5	6 6	6 6	6 7	6 7	8
9	6 0	6 1	6 1	6 2	6 3	6 3	6 4	6 4	6 5	6 6	6 6	6 7	6 8	6 8	9
10	6 0	6 1	6 1	6 2	6 3	6 4	6 4	6 5	6 6	6 6	6 7	6 8	6 9	6 9	10
11	6 0	6 1	6 2	6 2	6 3	6 4	6 5	6 5	6 6	6 7	6 8	6 9	6 9	6 10	11
12	6 0	6 1	6 2	6 3	6 3	6 4	6 5	6 6	6 7	6 8	6 9	6 9	6 10	6 11	12
13	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 6	6 7	6 8	6 9	6 10	6 11	6 12	13
14	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 7	6 8	6 9	6 10	6 11	6 12	6 13	14
15	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 8	6 9	6 10	6 11	6 12	6 13	6 14	15
16	6 0	6 1	6 2	6 3	6 5	6 6	6 7	6 8	6 9	6 10	6 12	6 13	6 14	6 15	16
17	6 0	6 1	6 2	6 4	6 5	6 6	6 7	6 9	6 10	6 11	6 12	6 14	6 15	6 16	17
18	6 0	6 1	6 3	6 4	6 5	6 7	6 8	6 9	6 10	6 12	6 13	6 14	6 16	6 17	18
19	6 0	6 1	6 3	6 4	6 6	6 7	6 8	6 10	6 11	6 13	6 14	6 15	6 17	6 18	19
20	6 0	6 1	6 3	6 4	6 6	6 7	6 9	6 10	6 12	6 13	6 15	6 16	6 18	6 19	20
21	6 0	6 2	6 3	6 5	6 6	6 8	6 9	6 11	6 12	6 14	6 16	6 17	6 19	6 20	21
22	6 0	6 2	6 3	6 5	6 6	6 8	6 10	6 11	6 13	6 15	6 16	6 18	6 20	6 21	22
23	6 0	6 2	6 3	6 5	6 7	6 9	6 10	6 12	6 14	6 15	6 17	6 19	6 21	6 22	23
24	6 0	6 2	6 4	6 5	6 7	6 9	6 11	6 13	6 14	6 16	6 18	6 20	6 22	6 24	24
25	6 0	6 2	6 4	6 6	6 7	6 9	6 11	6 13	6 15	6 17	6 19	6 21	6 23	6 25	25
26	6 0	6 2	6 4	6 6	6 8	6 10	6 12	6 14	6 16	6 18	6 20	6 22	6 24	6 26	26
27	6 0	6 2	6 4	6 6	6 8	6 10	6 12	6 14	6 16	6 19	6 21	6 23	6 25	6 27	27
28	6 0	6 2	6 4	6 6	6 9	6 11	6 13	6 15	6 17	6 19	6 22	6 24	6 26	6 28	28
29	6 0	6 2	6 4	6 7	6 9	6 11	6 13	6 16	6 18	6 20	6 22	6 25	6 27	6 29	29
30	6 0	6 2	6 5	6 7	6 9	6 12	6 14	6 16	6 19	6 21	6 23	6 26	6 28	6 31	30
31	6 0	6 2	6 5	6 7	6 10	6 12	6 14	6 17	6 19	6 22	6 24	6 27	6 29	6 32	31
32	6 0	6 2	6 5	6 8	6 10	6 13	6 15	6 18	6 20	6 23	6 25	6 28	6 31	6 33	32
33	6 0	6 3	6 5	6 8	6 10	6 13	6 16	6 18	6 21	6 24	6 26	6 29	6 32	6 34	33
34	6 0	6 3	6 5	6 8	6 11	6 14	6 16	6 19	6 22	6 25	6 27	6 30	6 33	6 36	34
35	6 0	6 3	6 6	6 8	6 11	6 14	6 17	6 20	6 23	6 25	6 28	6 31	6 34	6 37	35
36	6 0	6 3	6 6	6 9	6 12	6 15	6 18	6 20	6 23	6 26	6 29	6 32	6 36	6 39	36
37	6 0	6 3	6 6	6 9	6 12	6 15	6 18	6 21	6 24	6 27	6 31	6 34	6 37	6 40	37
38	6 0	6 3	6 6	6 9	6 13	6 16	6 19	6 22	6 25	6 28	6 32	6 35	6 38	6 42	38
39	6 0	6 3	6 6	6 10	6 13	6 16	6 20	6 23	6 26	6 29	6 33	6 36	6 40	6 43	39
40	6 0	6 3	6 7	6 10	6 13	6 17	6 20	6 24	6 27	6 31	6 34	6 38	6 41	6 45	40
41	6 0	6 3	6 7	6 10	6 14	6 17	6 21	6 25	6 28	6 32	6 35	6 39	6 43	6 46	41
42	6 0	6 4	6 7	6 11	6 14	6 18	6 22	6 25	6 29	6 33	6 37	6 40	6 44	6 48	42
43	6 0	6 4	6 7	6 11	6 15	6 19	6 22	6 26	6 30	6 34	6 38	6 42	6 46	6 50	43
44	6 0	6 4	6 8	6 12	6 15	6 19	6 23	6 27	6 31	6 35	6 39	6 43	6 47	6 52	44
45	6 0	6 4	6 8	6 12	6 16	6 20	6 24	6 28	6 32	6 36	6 41	6 45	6 49	6 53	45
46	6 0	6 4	6 8	6 12	6 17	6 21	6 25	6 29	6 33	6 38	6 42	6 46	6 51	6 55	46
47	6 0	6 4	6 9	6 13	6 17	6 22	6 26	6 30	6 35	6 39	6 44	6 48	6 53	6 57	47
48	6 0	6 4	6 9	6 13	6 18	6 22	6 27	6 31	6 36	6 41	6 45	6 50	6 55	6 59	48
49	6 0	6 5	6 9	6 14	6 18	6 23	6 28	6 32	6 37	6 42	6 47	6 52	6 57	7 2	49
50	6 0	6 5	6 10	6 14	6 19	6 24	6 29	6 34	6 39	6 44	6 49	6 54	6 59	7 4	50
51	6 0	6 5	6 10	6 15	6 20	6 25	6 30	6 35	6 40	6 45	6 50	6 56	7 1	7 6	51
52	6 0	6 5	6 10	6 15	6 21	6 26	6 31	6 36	6 41	6 47	6 52	6 58	7 3	7 9	52
53	6 0	6 5	6 11	6 16	6 21	6 27	6 32	6 38	6 43	6 49	6 54	7 0	7 6	7 11	53
54	6 0	6 5	6 11	6 17	6 22	6 28	6 33	6 39	6 45	6 50	6 56	7 2	7 8	7 14	54
55	6 0	6 6	6 11	6 17	6 23	6 29	6 35	6 40	6 46	6 52	6 59	7 4	7 11	7 17	55
56	6 0	6 6	6 12	6 18	6 24	6 30	6 36	6 42	6 48	6 54	7 1	7 7	7 13	7 20	56
57	6 0	6 6	6 12	6 19	6 25	6 31	6 37	6 44	6 50	6 56	7 3	7 10	7 16	7 23	57
58	6 0	6 6	6 13	6 19	6 26	6 32	6 39	6 45	6 52	6 59	7 6	7 12	7 20	7 27	58
59	6 0	6 7	6 13	6 20	6 27	6 33	6 40	6 47	6 54	7 1	7 8	7 15	7 23	7 30	59
60	6 0	6 7	6 14	6 21	6 28	6 35	6 42	6 49	6 56	7 4	7 11	7 19	7 26	7 34	60

TABLE VIII. (*continued*).—SEMI-DIURNAL AND SEMI-NOCTURNAL ARCHES, SHOWING THE TIME OF THE RISING AND SETTING OF THE SUN, MOON, OR EQUATORIAL STARS.

DECLINATION.

Lat.	14°	15°	16°	17°	18°	19°	20°	21°	21½°	22°	22½°	23°	23° 23′	Lat.
°	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	°
1	6 1	6 1	6 1	6 1	6 1	6 1	6 1	6 2	6 2	6 2	6 2	6 2	6 2	1
2	6 2	6 2	6 2	6 2	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	2
3	6 3	6 3	6 3	6 4	6 4	6 4	6 4	6 5	6 5	6 5	6 5	6 5	6 5	3
4	6 4	6 4	6 5	6 5	6 5	6 6	6 6	6 6	6 6	6 6	6 7	6 7	6 7	4
5	6 5	6 5	6 6	6 6	6 7	6 7	6 7	6 8	6 8	6 8	6 8	6 9	6 9	5
6	6 6	6 6	6 7	6 7	6 8	6 8	6 9	6 9	6 10	6 10	6 10	6 10	6 10	6
7	6 7	6 8	6 8	6 9	6 9	6 10	6 10	6 11	6 11	6 11	6 12	6 12	6 12	7
8	6 8	6 9	6 8	6 10	6 10	6 11	6 12	6 12	6 13	6 13	6 13	6 14	6 14	8
9	6 9	6 10	6 10	6 11	6 12	6 13	6 13	6 14	6 14	6 15	6 15	6 15	6 16	9
10	6 10	6 11	6 12	6 12	6 13	6 14	6 15	6 16	6 16	6 16	6 17	6 17	6 18	10
11	6 11	6 12	6 13	6 14	6 14	6 15	6 16	6 17	6 18	6 18	6 18	6 19	6 19	11
12	6 12	6 13	6 14	6 15	6 16	6 17	6 18	6 19	6 19	6 20	6 20	6 21	6 21	12
13	6 13	6 14	6 15	6 16	6 17	6 18	6 19	6 20	6 21	6 21	6 22	6 22	6 23	13
14	6 14	6 15	6 16	6 17	6 19	6 20	6 21	6 22	6 23	6 23	6 24	6 24	6 25	14
15	6 15	6 16	6 18	6 19	6 20	6 21	6 22	6 24	6 24	6 25	6 25	6 26	6 27	15
16	6 16	6 18	6 19	6 20	6 21	6 23	6 24	6 25	6 26	6 27	6 27	6 28	6 29	16
17	6 17	6 19	6 20	6 21	6 23	6 24	6 26	6 27	6 28	6 28	6 29	6 30	6 31	17
18	6 19	6 20	6 21	6 23	6 24	6 26	6 27	6 29	6 29	6 30	6 31	6 32	6 32	18
19	6 20	6 21	6 23	6 24	6 26	6 27	6 29	6 30	6 31	6 32	6 33	6 34	6 34	19
20	6 21	6 22	6 24	6 26	6 27	6 29	6 30	6 32	6 33	6 34	6 35	6 36	6 36	20
21	6 22	6 24	6 25	6 27	6 29	6 30	6 32	6 34	6 35	6 36	6 37	6 38	6 38	21
22	6 23	6 25	6 27	6 28	6 30	6 32	6 34	6 36	6 37	6 38	6 39	6 40	6 41	22
23	6 24	6 26	6 28	6 30	6 32	6 34	6 36	6 38	6 38	6 39	6 40	6 42	6 43	23
24	6 25	6 27	6 29	6 31	6 33	6 35	6 37	6 39	6 40	6 41	6 42	6 44	6 45	24
25	6 27	6 29	6 31	6 33	6 35	6 37	6 39	6 41	6 42	6 43	6 45	6 46	6 47	25
26	6 28	6 30	6 32	6 34	6 36	6 39	6 41	6 43	6 44	6 45	6 47	6 48	6 49	26
27	6 29	6 31	6 34	6 36	6 38	6 40	6 43	6 45	6 46	6 48	6 49	6 50	6 51	27
28	6 30	6 33	6 35	6 37	6 40	6 42	6 45	6 47	6 48	6 50	6 51	6 52	6 53	28
29	6 32	6 34	6 37	6 39	6 42	6 44	6 47	6 49	6 50	6 52	6 53	6 54	6 56	29
30	6 33	6 36	6 38	6 41	6 43	6 46	6 49	6 51	6 53	6 54	6 55	6 57	6 58	30
31	6 34	6 37	6 40	6 42	6 45	6 48	6 51	6 53	6 55	6 56	6 58	6 59	7 0	31
32	6 36	6 39	6 41	6 44	6 47	6 50	6 53	6 56	6 57	6 58	7 0	7 2	7 3	32
33	6 37	6 40	6 43	6 46	6 49	6 53	6 55	6 58	6 59	7 1	7 2	7 4	7 5	33
34	6 39	6 42	6 45	6 48	6 51	6 54	6 57	7 0	7 2	7 3	7 5	7 7	7 8	34
35	6 40	6 43	6 46	6 49	6 53	6 56	6 59	7 2	7 4	7 6	7 7	7 9	7 11	35
36	6 42	6 45	6 48	6 51	6 55	6 58	7 1	7 5	7 7	7 8	7 10	7 12	7 14	36
37	6 43	6 47	6 50	6 53	6 57	7 0	7 4	7 7	7 9	7 11	7 13	7 15	7 16	37
38	6 45	6 48	6 52	6 55	6 59	7 2	7 6	7 10	7 12	7 14	7 16	7 17	7 19	38
39	6 47	6 50	6 54	6 57	7 1	7 5	7 9	7 12	7 14	7 16	7 18	7 20	7 22	39
40	6 48	6 52	6 56	6 59	7 3	7 7	7 11	7 15	7 17	7 19	7 21	7 23	7 25	40
41	6 50	6 54	6 58	7 2	7 6	7 10	7 14	7 18	7 20	7 22	7 24	7 27	7 29	41
42	6 52	6 56	7 0	7 4	7 8	7 12	7 17	7 21	7 23	7 25	7 28	7 30	7 32	42
43	6 54	6 58	7 2	7 6	7 11	7 15	7 19	7 24	7 26	7 29	7 31	7 33	7 36	43
44	6 56	7 0	7 4	7 9	7 13	7 18	7 22	7 27	7 29	7 32	7 34	7 37	7 39	44
45	6 58	7 2	7 7	7 11	7 16	7 21	7 25	7 30	7 33	7 35	7 38	7 40	7 43	45
46	7 0	7 4	7 9	7 14	7 19	7 24	7 29	7 34	7 36	7 39	7 42	7 44	7 47	46
47	7 2	7 7	7 12	7 17	7 22	7 27	7 32	7 37	7 40	7 43	7 46	7 48	7 51	47
48	7 4	7 9	7 14	7 19	7 25	7 30	7 35	7 41	7 44	7 47	7 50	7 53	7 55	48
49	7 7	7 12	7 17	7 22	7 28	7 33	7 39	7 45	7 48	7 51	7 54	7 57	8 0	49
50	7 9	7 14	7 20	7 25	7 31	7 37	7 43	7 49	7 52	7 55	7 58	8 2	8 5	50
51	7 12	7 17	7 23	7 29	7 35	7 41	7 47	7 53	7 56	8 0	8 3	8 6	8 10	51
52	7 14	7 20	7 26	7 32	7 38	7 45	7 51	7 58	8 1	8 5	8 8	8 12	8 15	52
53	7 17	7 23	7 29	7 36	7 42	7 49	7 56	8 2	8 6	8 10	8 13	8 17	8 21	53
54	7 20	7 27	7 33	7 40	7 46	7 53	8 0	8 8	8 11	8 15	8 19	8 23	8 25	54
55	7 23	7 30	7 37	7 44	7 51	7 58	8 5	8 13	8 17	8 21	8 25	8 29	8 33	55
56	7 27	7 34	7 41	7 48	7 55	8 3	8 11	8 19	8 23	8 27	8 32	8 36	8 40	56
57	7 30	7 37	7 45	7 52	8 0	8 8	8 16	8 25	8 29	8 34	8 39	8 43	8 48	57
58	7 34	7 42	7 49	7 57	8 5	8 14	8 22	8 32	8 36	8 41	8 46	8 51	8 56	58
59	7 38	7 46	7 54	8 2	8 11	8 20	8 29	8 39	8 44	8 49	8 54	9 0	9 5	59
60	7 42	7 51	7 59	8 8	8 17	8 26	8 36	8 47	8 52	8 58	9 3	9 9	9 15	60

Table IX.—Distance of the Sea Horizon uncorrected for effects of Refraction.*

Height.	Distance.	Height.	Distance.	Height.	Distance.	Height.	Distance.	Height.	Distance.	Height.	Distance.
Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.
1·1	1	390	21	1487	41	3293	61	9032	101	17608	141
3·5	2	428	22	1561	42	3513	63	9393	103	18111	143
8·0	3	468	23	1636	43	3740	65	9760	105	18622	145
14·2	4	510	24	1713	44	3974	67	10135	107	19140	147
22·1	5	550	25	1792	45	4213	69	10518	109	19664	149
31·9	6	598	26	1872	46	4461	71	10908	111	20197	151
43·3	7	645	27	1954	47	4716	73	11304	113	20736	153
56·6	8	694	28	2039	48	4976	75	11709	115	21282	155
71·7	9	744	29	2124	49	5249	77	12120	117	21836	157
88·5	10	797	30	2212	50	5524	79	12538	119	22397	159
107	11	850	31	2301	51	5808	81	12966	121	22964	161
127	12	906	32	2393	52	6098	83	13397	123	23540	163
149	13	964	33	2485	53	6394	85	13836	125	24121	165
173	14	1023	34	2581	54	6700	87	14282	127	24711	167
199	15	1084	35	2677	55	7012	89	14737	129	25307	169
226	16	1147	36	2775	56	7332	91	15197	131	25911	171
256	17	1211	37	2875	57	7656	93	15664	133	26521	173
287	18	1278	38	2977	58	7987	95	16139	135	27139	175
319	19	1346	39	3081	59	8330	97	16622	137	27764	177
354	20	1416	40	3186	60	8678	99	17111	139	28396	179

(*Approximately* the distance visible in miles is the square root of the height in feet, an accidental relation easy to remember.)

* The effects of refraction at low angles are very variable, but in ordinary cases, if the height of observer be supposed to be increased by one-third, the distance of the visible sea horizon will not exceed the tabular value corresponding to the revised entry. Extraordinary cases are those of mirage, &c., for which no general rule can be given.

TABLE X.—Values of $\dfrac{2 \operatorname{Sin}^2 \frac{1}{2} \text{hour} \angle}{\operatorname{Sin} 1''}$.

Seconds.	0^m	1^m	2^m	3^m	4^m	5^m	6^m	7^m	8^m	9^m	10^m	11^m	12^m	13^m	14^m	15^m	16^m	17^m	18^m	19^m
	Hour Angles in Time.																			
0	0	2	8	18	31	49	71	96	126	159	196	237	283	332	385	442	502	567	636	708
1	0	2	8	18	32	49	71	97	126	160	197	238	283	333	386	443	503	568	637	710
2	0	2	8	18	32	50	71	97	127	160	198	239	284	333	387	444	505	569	638	711
3	0	2	8	18	32	50	72	98	127	161	198	240	285	334	387	445	506	570	639	712
4	0	2	8	18	32	50	72	98	128	161	199	240	286	335	388	446	507	572	641	713
5	0	2	8	19	33	51	73	98	128	162	200	241	287	336	389	446	508	573	642	715
6	0	2	9	19	33	51	73	99	129	163	200	242	287	337	390	447	509	574	643	716
7	0	2	9	19	33	51	73	99	129	163	201	243	288	338	391	448	510	575	644	717
8	0	2	9	19	33	52	74	100	130	164	202	243	289	339	392	449	511	576	645	718
9	0	3	9	19	34	52	74	100	130	164	202	244	290	339	393	450	512	577	646	720
10	0	3	9	20	34	52	75	101	131	165	203	245	291	340	394	451	513	578	648	721
11	0	3	9	20	34	53	75	101	131	166	204	245	291	341	395	452	514	579	649	722
12	0	3	9	20	35	53	75	102	132	166	204	246	292	342	396	453	515	581	650	723
13	0	3	10	20	35	53	76	102	133	167	205	247	293	343	397	454	516	582	651	725
14	0	3	10	20	35	54	76	103	133	167	206	248	294	344	398	455	517	583	652	726
15	0	3	10	21	35	54	77	103	134	168	206	248	295	345	399	456	518	584	654	727
16	0	3	10	21	36	54	77	104	134	169	207	249	295	345	399	457	519	585	655	728
17	0	3	10	21	36	55	77	104	135	169	208	250	296	346	400	458	520	586	656	730
18	0	3	10	21	36	55	78	105	135	170	208	251	297	347	401	459	521	587	657	731
19	0	3	10	22	37	55	78	105	136	170	209	251	298	348	402	461	522	588	658	732
20	0	3	11	22	37	56	79	106	136	171	210	252	299	349	403	461	524	590	660	733
21	0	4	11	22	37	56	79	106	137	172	210	253	299	350	404	463	525	591	661	735
22	0	4	11	22	37	56	80	107	137	172	211	254	300	351	405	463	526	592	662	736
23	0	4	11	22	38	57	80	107	138	173	212	254	301	352	406	464	527	593	663	737
24	0	4	11	23	38	57	80	107	138	173	212	255	302	352	407	465	528	594	664	738
25	0	4	11	23	38	58	81	108	139	174	213	256	303	353	408	466	529	595	666	740
26	0	4	12	23	39	58	81	108	140	175	214	257	303	354	409	467	530	596	667	741
27	0	4	12	23	39	58	82	109	140	175	214	257	304	355	410	468	531	598	668	742
28	0	4	12	24	39	59	82	109	141	176	215	258	305	356	411	470	532	599	669	744

TABLE X.—*continued.*

Seconds.	Hour Angles in Time.																			
	0m	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m	11m	12m	13m	14m	15m	16m	17m	18m	19m
29	0	4	12	24	39	59	82	110	141	177	216	259	306	357	412	470	533	600	670	745
30	1	4	12	24	40	59	83	110	142	177	216	260	307	358	413	471	534	601	672	746
31	1	4	12	24	40	60	83	111	142	178	217	260	307	359	414	473	535	602	673	747
32	1	5	13	24	40	60	84	111	143	178	218	261	308	359	415	474	536	603	674	749
33	1	5	13	25	41	60	84	112	143	179	218	262	309	360	415	475	538	604	675	750
34	1	5	13	25	41	61	85	112	144	180	219	263	310	361	416	476	539	606	676	751
35	1	5	13	25	41	61	85	113	145	180	220	263	311	362	417	477	540	607	678	753
36	1	5	13	25	41	62	85	113	145	181	221	264	312	363	418	478	541	608	679	754
37	1	5	13	26	42	62	86	114	146	182	221	265	312	364	419	479	542	609	680	755
38	1	5	14	26	42	62	86	114	146	182	222	266	313	365	420	480	543	610	681	756
39	1	5	14	26	42	63	87	115	147	183	223	266	314	366	421	481	544	611	683	758
40	1	5	14	26	43	63	87	115	147	183	223	267	315	367	422	482	545	612	684	759
41	1	6	14	27	43	63	88	116	148	184	224	268	316	367	423	483	546	614	685	760
42	1	6	14	27	43	64	88	116	149	185	225	269	317	368	424	484	547	615	686	761
43	1	6	14	27	44	64	89	117	149	185	225	269	317	369	425	485	548	616	687	763
44	1	6	15	27	44	64	89	117	150	186	226	270	318	370	426	486	549	617	689	764
45	1	6	15	28	44	65	89	118	150	187	227	271	319	371	427	487	551	618	690	765
46	1	6	15	28	45	65	90	118	151	187	228	272	320	372	428	488	552	619	691	767
47	1	6	15	28	45	66	90	119	151	188	228	273	321	373	429	489	553	621	692	768
48	1	6	15	28	45	66	91	119	152	188	229	273	322	374	430	490	554	622	694	769
49	1	6	16	29	45	66	91	120	153	189	230	274	322	375	431	491	555	623	695	771
50	1	7	16	29	46	67	92	120	153	190	230	275	323	376	432	492	556	624	696	772
51	1	7	16	29	46	67	92	121	154	190	231	276	324	376	433	493	557	625	697	773
52	2	7	16	29	46	68	93	121	154	191	232	276	325	377	434	494	558	626	698	774
53	2	7	16	30	47	68	93	122	155	192	232	277	326	378	435	495	559	628	700	776
54	2	7	16	30	47	68	93	122	155	192	233	278	327	379	436	496	560	629	701	777
55	2	7	17	30	47	69	94	123	156	193	234	279	327	380	437	497	562	630	702	778
56	2	7	17	30	48	69	94	124	157	194	235	279	328	381	438	498	563	631	703	780
57	2	7	17	31	48	69	95	124	157	194	235	280	329	382	439	499	564	632	705	781
58	2	8	17	31	48	70	95	125	158	195	236	281	330	383	440	500	565	633	706	782
59	2	8	17	31	49	70	96	125	158	196	237	282	331	384	441	501	566	635	707	784

TABLE XI.—NUMBER OF GEOGRAPHICAL MILES,* OR MINUTES OF THE EQUATOR CONTAINED IN A DEGREE OF LONGITUDE UNDER EACH PARALLEL OF LATITUDE, ON THE SUPPOSITION OF THE EARTH'S SPHEROIDAL SHAPE WITH A COMPRESSION OF $\frac{1}{304}$.

Parallel of Latitude.	Length of Degree.	Parallel of Latitude.	Length of Degree.	Parallel of Latitude.	Length of Degree.	Parallel of Latitude.	Length of Degree.	Parallel of Latitude.	Length of Degree.	Parallel of Latitude.	Length of Degree.
°	′	°	′	°	′	°	′	°	′	°	′
0	60·000	16	57·690	31	51·475	46	41·750	61	29·161	76	14·560
1	59·991	17	57·394	32	50·930	47	40·992	62	28·240	77	13·539
2	59·964	18	57·081	33	50·370	48	40·220	63	27·310	78	12·514
3	59·918	19	56·751	34	49·793	49	39·437	64	26·372	79	11·485
4	59·854	20	56·403	35	49·202	50	38·642	65	25·426	80	10·452
5	59·773	21	56·038	36	48·596	51	37·834	66	24·471	81	9·416
6	59·673	22	55·657	37	47·975	52	37·015	67	23·509	82	8·377
7	59·556	23	55·258	38	47·339	53	36·185	68	22·540	83	7·336
8	59·419	24	54·842	39	46·688	54	35·343	69	21·564	84	6·292
9	59·266	25	54·410	40	46·021	55	34·490	70	20·581	85	5·246
10	59·094	26	53·962	41	45·346	56	33·627	71	19·592	86	4·199
11	58·905	27	53·496	42	44·654	57	32·754	72	18·596	87	3·150
12	58·697	28	53·015	43	43·948	58	31·870	73	17·595	88	2·101
13	58·472	29	52·518	44	43·229	59	30·977	74	16·588	89	1·050
14	58·229	30	52·004	45	42·495	60	30·074	75	15·577	90	0·000
15	57·968										

* To convert to Statute miles, multiply by 1·15.

TABLE XII.—TABLE FOR CONVERTING STATUTE INTO GEOGRAPHICAL MILES.

Stat. Miles.	Geo. Miles.	Stat. Miles.	Geo. Miles.	Stat. Miles.	Geo. Miles.	Stat. Miles.	Geo. Miles.
1·00	0 87	13·25	11·50	25·50	22·11	37·75	32·78
1·25	1·08	13·50	11·72	25·75	22·36	38·00	33·00
1·50	1·30	13·75	11·94	26·00	22·58	38·25	33·21
1·75	1·52	14·00	12·16	26·25	22·80	38·50	33·43
2·00	1·74	14·25	12·37	26·50	23·01	38·75	33·65
2·25	1·95	14·50	12·59	26·75	23·23	39·00	33·87
2·50	2·17	14·75	12·81	27·00	23·45	39·25	34·08
2·75	2·39	15·00	13·03	27·25	23·66	39·50	34·30
3·00	2·60	15·25	13·24	27·50	23·88	39·75	34·52
3·25	2·82	15·50	13·56	27·75	24·10	40·00	34·73
3·50	3·04	15·75	13·68	28 00	24·31	40·25	34·95
3·75	3·26	16·00	13·89	28·25	24·53	40·50	35·17
4·00	3·48	16·25	14·11	28·50	24·75	40·75	35·38
4·25	3·70	16·50	14·33	28·75	24 97	41·00	35·60
4·50	3·91	16·75	14·55	29·00	25·18	41·25	35·82
4·75	4·12	17·00	14·76	29·25	25·40	41·50	36·04
5·00	4·34	17·25	14·98	29·50	25·64	41·75	36·25
5·25	4·56	17·50	15·20	29·75	25·83	42·00	36·47
5·50	4·78	17·75	15·41	30·00	26·05	42·25	36·69
5·75	4·99	18·00	15·63	30·25	26·27	42·50	36·90
6·00	5·21	18·25	15·85	30·50	26·48	42·75	37·12
6·25	5·43	18·50	16·06	30·75	26·70	43·00	37·34
6·50	5·64	18·75	16·28	31·00	26·92	43·25	37·55
6·75	5·86	19·00	16·50	31·25	27·13	43·50	37·77
7·00	6·08	19·25	16·72	31·50	27·35	43·75	37·99
7·25	6·30	19·50	16·93	31·75	27·57	44·00	38·21
7·50	6·51	19·75	17·15	32·00	27·79	44·25	38·42
7·75	6·73	20·00	17·37	32·25	28·01	44·50	38·64
8·00	6·95	20·25	17·58	32·50	28·22	44·75	38·86
8·25	7·16	20·50	17·80	32·75	28·44	45·00	39·07
8·50	7·38	20·75	18·02	33·00	28·66	45·25	39·29
8·75	7·60	21·00	18·24	33·25	28·87	45·50	39·51
9·00	7·81	21·25	18·45	33·50	29·09	45·75	39·72
9·25	8·03	21·50	18·67	33·75	29·31	46·00	39·94
9·50	8·25	21·75	18·89	34·00	29·53	46·25	40·16
9·75	8·47	22·00	19·10	34·25	29·74	46·50	40·38
10·00	8·68	22·25	19·32	34·50	29·96	46·75	40·59
10·25	8·90	22·50	19·54	34·75	30·18	47·00	40·81
10·50	9·12	22·75	19·76	35·00	30·39	47·25	41·03
10·75	9·33	23·00	19·97	35·25	30·61	47·50	41·24
11·00	9·55	23·25	20·19	35·50	30·83	47·75	41·46
11·25	9·77	23·50	20·41	35·75	31·04	48·00	41·68
11·50	9·99	23·75	20·62	36·00	31·26	48·25	41·89
11·75	10·20	24·00	20·34	36·25	31·48	48·50	42·11
12·00	10·42	24·25	21·06	36·50	31·70	48·75	42·33
12·25	10·64	24·50	21·28	36·75	31·91	49·00	42·55
12·50	10·85	24·75	21·49	37·00	32·13	49·25	42·76
12·75	11·07	25·00	21·71	37·25	32·35	49·50	42·98
13·00	11·29	25·25	21·93	37·50	32·56	49·75	43·20
						50·00	43·42

Table XIII.—For converting Geographical into Statute Miles.

Geo. Miles.	Stat. Miles.	Geo. Miles.	Stat. Miles.	Geo. Miles.	Stat. Miles.	Geo. Miles.	Stat. Miles.
1·00	1·15	13·25	15·26	25·50	29·36	37·75	43·34
1·25	1·44	13·50	15·54	25·75	29·66	38·00	43·63
1·50	1·73	13·75	15·83	26·00	29·94	38·25	43·92
1·75	2·01	14·00	16·12	26·25	30·23	38·50	44·20
2·00	2·30	14·25	16·41	26·50	30·52	38·75	44·49
2·25	2·59	14·50	16·70	26·75	30·81	39·00	44·78
2·50	2·88	14·75	16·98	27·00	31·09	39·25	45·07
2·75	3·17	15·00	17·27	27·25	31·38	39·50	45·35
3·00	3·45	15·25	17·56	27·50	31·67	39·75	45·64
3·25	3·74	15·50	17·85	27·75	31·95	40·00	45·93
3·50	4·03	15·75	18·14	28·00	32·24	40·25	46·21
3·75	4·32	16·00	18·42	28·25	32·53	40·50	46·50
4·00	4·61	16·25	18·71	28·50	32·81	40·75	46·79
4·25	4·89	16·50	19·00	28·75	33·10	41·00	47·07
4·50	5·18	16·75	19·28	29·00	33·39	41·25	47·36
4·75	5·47	17·00	19·57	29·25	33·68	41·50	47·66
5·00	5·76	17·25	19·86	29·50	33·96	41·75	47·95
5·25	6·04	17·50	20·15	29·75	34·25	42·00	48·23
5·50	6·33	17·75	20·44	30·00	34·54	42·25	48·52
5·75	6·62	18·00	20·73	30·25	34·82	42·50	48·81
6·00	6·91	18·25	21·01	30·50	35·11	42·75	49·09
6·25	7·20	18·50	21·30	30·75	35·40	43·00	49·38
6·50	7·48	18·75	21·59	31·00	35·68	43·25	49·67
6·75	7·77	19·00	21·88	31·25	35·97	43·50	49·95
7·00	8·06	19·25	22·17	31·50	36·26	43·75	50·24
7·25	8·35	19·50	22·45	31·75	36·55	44·00	50·33
7·50	8·64	19·75	22·74	32·00	36·83	44·25	50·82
7·75	8·92	20·00	23·03	32·25	37·12	44·50	51·10
8·00	9·21	20·25	23·32	32·50	37·41	44·75	51·39
8·25	9·50	20·50	23·61	32·75	37·69	45·00	51·68
8·50	9·79	20·75	23·89	33·00	37·98	45·25	51·96
8·75	10·07	21·00	24·18	33·25	38·27	45·50	52·25
9·00	10·36	21·25	24·47	33·50	38·55	45·75	52·54
9·25	10·65	21·50	24·76	33·75	38·84	46·00	52·83
9·50	10·94	21·75	25·04	34·00	39·13	46·25	53·11
9·75	11·23	22·00	25·33	34·25	39·42	46·50	53·40
10·00	11·51	22·25	25·62	34·50	39·70	46·75	53·69
10·25	11·80	22·50	25·91	34·75	39·99	47·00	53·97
10·50	12·09	22·75	26·20	35·00	40·28	47·25	54·26
10·75	12·38	23·00	26·48	35·25	40·56	47·50	54·49
11·00	12·67	23·25	26·77	35·50	40·85	47·75	54·83
11·25	12·95	23·50	27·06	35·75	41·13	48·00	55·12
11·50	13·24	23·75	27·35	36·00	41·42	48·25	55·41
11·75	13·53	24·00	27·64	36·25	41·72	48·50	55·70
12·00	13·82	24·25	27·92	36·50	42·01	48·75	55·98
12·25	14·11	24·50	28·21	36·75	42·30	49·00	56·27
12·50	14·39	24·75	28·50	37·00	42·58	49·25	56·56
12·75	14·68	25·00	28·79	37·25	42·77	49·50	56·84
13·00	14·97	25·25	29·07	37·50	43·06	49·75	57·13
						50·00	57·42

Table XIV.—Comparison of Thermometer Scales.

Fahrenheit.	Réaumur.	Centigrade.	Fahrenheit.	Réaumur.	Centigrade.	Fahrenheit.	Réaumur.	Centigrade.
°	°	°	°	°	°	°	°	°
			33	+0·4	+0·6	67	+15·6	+19·4
0	−14·2	−17·8	34	0·9	1·1	68	16·0	20·0
1	13·8	17·2	35	1·3	1·7	69	16·4	20·6
2	13·3	16·7	36	1·8	2·2	70	16·9	21·1
3	12·9	16·1	37	2·2	2·8	71	17·3	21·7
4	12·4	15·6	38	2·7	3·3	72	17·8	22·2
5	12·0	15·0	39	3·1	3·9	73	18·2	22·8
6	11·6	14·4	40	3·6	4·4	74	18·7	23·3
7	11·1	13·9	41	4·0	5·0	75	19·1	23·9
8	10·7	13·3	42	4·4	5·6	76	19·6	24·4
9	10·2	12·8	43	4·9	6·1	77	20·0	25·0
10	9·8	12·2	44	5·3	6·7	78	20·4	25·6
11	9·3	11·7	45	5·8	7·2	79	20·9	26·1
12	8·9	11·1	46	6·2	7·8	80	21·3	26·7
13	8·4	10·6	47	6·7	8·3	81	21·8	27·2
14	8·0	10·0	48	7·1	8·9	82	22·2	27·8
15	7·6	9·4	49	7·6	9·4	83	22·7	28·3
16	7·1	8·9	50	8·0	10·0	84	23·1	28·9
17	6·7	8·3	51	8·4	10·6	85	23·6	29·4
18	6·2	7·8	52	8·9	11·1	86	24·0	30·0
19	5·8	7·2	53	9·3	11·7	87	24·4	30·6
20	5·3	6·7	54	9·8	12·2	88	24·9	31·1
21	4·9	6·1	55	10·2	12·8	89	25·3	31·7
22	4·4	5·6	56	10·7	13·3	90	25·8	32·2
23	4·0	5·0	57	11·1	13·9	91	26·2	32·8
24	3·6	4·4	58	11·6	14·4	92	26·7	33·3
25	3·1	3·9	59	12·0	15·0	93	27·1	33·9
26	2·7	3·3	60	12·4	15·6	94	27·6	34·4
27	2·2	2·8	61	12·9	16·1	95	28·0	35·0
28	1·8	2·2	62	13·3	16·7	96	28·4	35·6
29	1·3	1·7	63	13·8	17·2	97	28·9	36·1
30	0·9	1·1	64	14·2	17·8	98	29·3	36·7
31	−0·4	−0·6	65	14·7	18·3	99	29·8	37·2
32	0·0	0·0	66	+15·1	+18·9	100	+30·2	+37·8

x° Réaumur $= (32^\circ + \frac{9}{4}x^\circ)$ Fahrenheit $= \frac{5}{4}x^\circ$ Centigrade.

x° Centigrade $= (32^\circ + \frac{9}{5}x^\circ)$ Fahrenheit $= \frac{4}{5}x^\circ$ Réaumur.

x° Fahrenheit $= \frac{4}{9}(x^\circ - 32)$ Réaumur $= \frac{5}{9}(x^\circ - 32^\circ)$ Centigrade.

Table XV.—For converting English Inches and Tenths into Millimètres.

English inches and tenths.	Millim.	English inches and tenths.	Millim.	English inches and tenths.	Millim.	English inches and tenths.	Millim.	English inches and tenths.	Millim.
12·0	304·79	16·0	406·39	20·0	507·99	24·0	609·59	28·0	711·19
1	307·33	1	408·93	1	510·53	1	612·13	1	713·73
2	309·87	2	411·47	2	513·07	2	614·67	2	716·27
3	312·41	3	414·01	3	515·61	3	617·21	3	718·81
4	314·95	4	416·55	4	518·15	4	619·75	4	721·35
5	317·49	5	419·09	5	520·69	5	622·29	5	723·89
6	320·03	6	421·63	6	523·23	6	624·83	6	726·43
7	322·57	7	424·17	7	525·77	7	627·37	7	728·97
8	325·11	8	426·71	8	528·31	8	629·91	8	731·51
9	327·65	9	429·25	9	530·85	9	632·45	9	734·05
13·0	330·19	17·0	431·79	21·0	533·39	25·0	634·99	29·0	736·59
1	332·73	1	434·33	1	535·93	1	637·53	1	739·13
2	335·27	2	436·87	2	538·47	2	640·07	2	741·67
3	337·81	3	439·41	3	541·01	3	642·61	3	744·21
4	340·35	4	441·95	4	543·55	4	645·15	4	746·75
5	342·89	5	444·49	5	546·09	5	647·69	5	749·29
6	345·43	6	447·03	6	548·63	6	650·23	6	751·83
7	347·97	7	449·57	7	551·17	7	652·77	7	754·37
8	350·51	8	452·11	8	553·71	8	655·31	8	756·91
9	353·05	9	454·65	9	556·25	9	657·85	9	759·45
14·0	355·59	18·0	457·19	22·0	558·79	26·0	660·39	30·0	761·99
1	358·13	1	459·73	1	561·33	1	662·93	1	764·53
2	360·67	2	462·27	2	563·87	2	665·47	2	767·07
3	363·21	3	464·81	3	566·41	3	668·01	3	769·61
4	365·75	4	467·35	4	568·95	4	670·55	4	772·15
5	368·29	5	469·89	5	571·49	5	673·09	5	774·69
6	370·83	6	472·43	6	574·03	6	675·63	6	777·23
7	373·37	7	474·97	7	576·57	7	678·17	7	779·77
8	375·91	8	477·51	8	579·11	8	680·71	8	782·31
9	378·45	9	480·05	9	581·65	9	683·25	9	784·85
15·0	380·99	19·0	482·59	23·0	584·19	27·0	685·79	31·0	787·39
1	383·53	1	485·13	1	586·73	1	688·33	1	789·93
2	386·07	2	487·67	2	589·27	2	690·87	2	792·47
3	388·61	3	490·21	3	591·81	3	693·41	3	795·01
4	391·15	4	492·75	4	594·35	4	695·95	4	797·55
5	393·69	5	495·29	5	596·89	5	698·49		
6	396·23	6	497·83	6	599·43	6	701·03		
7	398·77	7	500·37	7	601·97	7	703·57		
8	401·31	8	502·91	8	604·51	8	706·11		
9	403·85	9	505·45	9	607·05	9	708·65		

Parts to be added for Hundredths of an Inch.

1	2	3	4	5	6	7	8	9
·254	·508	·762	1·016	1·270	1·524	1·778	2·032	2·286

TABLE XVI.—CONVERSION OF MÈTRES INTO ENGLISH FEET.

1 to 210.

Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.
1	3·28	36	118·11	71	232·94	106	347·78	141	462·61	176	577·44
2	6·56	37	121·39	72	236·22	7	351·06	42	465·89	77	580·72
3	9·84	38	124·67	73	239·51	8	354·34	43	469·17	78	584·00
4	13·12	39	127·96	74	242·79	9	357·62	44	472·45	79	587·28
5	16·40	40	131·24	75	246·07	10	360·90	45	475·73	80	590·56
6	19·69	41	134·52	76	249·35	111	364·18	146	479·01	181	593·84
7	22·97	42	137·80	77	252·63	12	367·46	47	482·29	82	597·12
8	26·25	43	141·08	78	255·91	13	370·74	48	485·57	83	600·40
9	29·53	44	144·36	79	259·19	14	374·02	49	488·85	84	603·69
10	32·81	45	147·64	80	262·47	15	377·30	50	492·13	85	606·97
11	36·09	46	150·92	81	265·75	116	380·58	151	495·42	186	610·25
12	39·37	47	154·20	82	269·03	17	383·87	52	498·70	87	613·53
13	42·65	48	157·48	83	272·31	18	387·15	53	501·98	88	616·81
14	45·93	49	160·76	84	275·60	19	390·43	54	505·26	89	620·09
15	49·21	50	164·04	85	278·88	20	393·71	55	508·54	90	623·37
16	52·49	51	167·33	86	282·16	121	396·99	156	511·82	191	626·65
17	55·78	52	170·61	87	285·44	22	400·27	57	515·10	92	629·93
18	59·06	53	173·89	88	288·72	23	403·55	58	518·38	93	633·21
19	62·34	54	177·17	89	292·00	24	406·83	59	521·66	94	636·49
20	65·62	55	180·45	90	295·28	25	410·11	60	524·94	95	639·78
21	68·90	56	183·73	91	298·56	126	413·39	161	528·22	196	643·06
22	72·18	57	187·01	92	301·84	27	416·67	62	531·51	97	646·34
23	75·46	58	190·29	93	305·12	28	419·96	63	534·79	98	649·62
24	78·74	59	193·57	94	308·40	29	423·24	64	538·07	99	652·90
25	82·02	60	196·85	95	311·69	30	426·52	65	541·35	200	656·18
26	85·30	61	200·13	96	314·97	131	429·80	166	544·63	201	659·46
27	88·58	62	203·42	97	318·25	32	433·08	67	547·91	2	662·74
28	91·87	63	206·70	98	321·53	33	436·36	68	551·19	3	666·02
29	95·15	64	209·98	99	324·81	34	439·64	69	554·47	4	669·30
30	98·43	65	213·26	100	328·09	35	442·92	70	557·75	5	672·58
31	101·71	66	216·54	101	331·37	136	446·20	171	561·03	206	675·87
32	104·99	67	219·82	2	334·65	37	449·48	72	564·31	7	679·15
33	108·27	68	223·10	3	337·93	38	452·76	73	567·60	8	682·43
34	111·55	69	226·38	4	341·21	39	456·04	74	570·88	9	685·71
35	114·83	70	229·66	5	344·49	40	459·33	75	574·16	10	688·99

TABLE XVI. (*continued*).—CONVERSION OF MÈTRES INTO ENGLISH FEET.

211 to 420.

Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.
211	692·27	246	807·10	281	921·93	316	1036·76	351	1151·60	386	1266·43
12	695·55	47	810·38	82	925·21	17	1040·05	52	1154·88	87	1269·71
13	698·83	48	813·66	83	928·49	18	1043·33	53	1158·16	88	1272·99
14	702·11	49	816·94	84	931·78	19	1046·61	54	1161·44	89	1276·27
15	705·39	50	820·22	85	935·06	20	1049·89	55	1164·72	90	1279·55
216	708·67	251	823·51	286	938·34	321	1053·17	356	1168·00	391	1282·83
17	711·96	52	826·79	87	941·62	22	1056·45	57	1171·28	92	1286·11
18	715·24	53	830·07	88	944·90	23	1059·73	58	1174·56	93	1289·39
19	718·52	54	833·35	89	948·18	24	1063·01	59	1177·84	94	1292·67
20	721·80	55	836·63	90	951·46	25	1066·29	60	1181·12	95	1295·95
221	725·08	256	839·91	291	954·74	326	1069·57	361	1184·40	396	1299·23
22	728·36	57	843·19	92	958·02	27	1072·85	62	1187·69	97	1302·52
23	731·64	58	846·47	93	961·30	28	1076·13	63	1190·97	98	1305·80
24	734·92	59	849·75	94	964·58	29	1079·42	64	1194·25	99	1309·08
25	738·20	60	853·03	95	967·87	30	1082·70	65	1197·53	400	1312·36
226	741·48	261	856·31	296	971·15	331	1085·98	366	1200·81	401	1315·64
27	744·76	62	859·60	97	974·43	32	1089·26	67	1204·09	2	1318·92
28	748·05	63	862·88	98	977·71	33	1092·54	68	1207·37	3	1322·20
29	751·33	64	866·16	99	980·99	34	1095·82	69	1210·65	4	1325·48
30	754·61	65	869·44	300	984·27	35	1099·10	70	1213·93	5	1328·76
231	757·89	266	872·72	301	987·55	336	1102·38	371	1217·21	406	1332·05
32	761·17	67	876·00	2	990·83	37	1105·66	72	1220·49	7	1335·33
33	764·45	68	879·28	3	994·11	38	1108·94	73	1223·78	8	1338·61
34	767·73	69	882·56	4	997·39	39	1112·22	74	1227·06	9	1341·89
35	771·01	70	885·84	5	1000·67	40	1115·51	75	1230 34	10	1345·17
236	774·29	271	889·12	306	1003·96	341	1118·79	376	1233·62	411	1348·45
37	777·57	72	892·40	7	1007·24	42	1122 07	77	1236·90	12	1351·73
38	780·85	73	895·69	8	1010·52	43	1125·35	78	1240·18	13	1355·01
39	784·13	74	898·97	9	1013·80	44	1128·63	79	1243·46	14	1358·29
40	787·42	75	902·25	10	1017·08	45	1131·91	80	1246·74	15	1361·57
241	790·70	276	905·53	311	1020·36	346	1135·19	381	1250·02	416	1364·85
42	793·98	77	908·81	12	1023·64	47	1138·47	82	1253·30	17	1368·13
43	797·26	78	912·09	13	1026·92	48	1141·75	83	1256·58	18	1371·42
44	800·54	79	915·37	14	1030·20	49	1145·03	84	1259·87	19	1374·70
45	803·82	80	918·65	15	1033·48	50	1148·31	85	1263·15	20	1377·98

TABLE XVI. (*continued*).—CONVERSION OF MÈTRES INTO ENGLISH FEET.

421 to 630.

Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.
421	1381·26	456	1496·09	491	1610·92	526	1725·75	561	1840·58	596	1955·42
22	1384·54	57	1499·37	92	1614·20	27	1729·03	62	1843·87	97	1958·70
23	1387·82	58	1502·65	93	1617·48	28	1732·31	63	1847·15	98	1961·98
24	1391·10	59	1505·93	94	1620·76	29	1735·60	64	1850·43	99	1965·26
25	1394·38	60	1509·21	95	1624·05	30	1738·88	65	1853·71	600	1968·54
426	1397·66	461	1512·49	496	1627·33	531	1742·16	566	1856·99	601	1971·82
27	1400·94	62	1515·78	97	1630·61	32	1745·44	67	1860·27	2	1975·10
28	1404·22	63	1519·06	98	1633·89	33	1748·72	68	1863·55	3	1978·38
29	1407·51	64	1522·34	99	1637·17	34	1752·00	69	1866·83	4	1981·66
30	1410·79	65	1525·62	500	1640·45	35	1755·28	70	1870·11	5	1984·94
431	1414·07	466	1528·90	501	1643·73	536	1758·56	571	1873·39	606	1988·22
32	1417·35	67	1532·18	2	1647·01	37	1761·84	72	1876·67	7	1991·51
33	1420·63	68	1535·46	3	1650·29	38	1765·12	73	1879·95	8	1994·79
34	1423·91	69	1538·74	4	1653·57	39	1768·40	74	1883·23	9	1998·07
35	1427·19	70	1542·02	5	1656·85	40	1771·69	75	1886·52	10	2001·35
436	1430·47	471	1545·30	506	1660·13	541	1774·97	576	1889·80	611	2004·63
37	1433·75	72	1548·58	7	1663·42	42	1778·25	77	1893·08	12	2007·91
38	1437·03	73	1551·87	8	1666·70	43	1781·53	78	1896·36	13	2011·19
39	1440·31	74	1555·15	9	1669·98	44	1784·81	79	1899·64	14	2014·47
40	1443·60	75	1558·43	10	1673·26	45	1788·09	80	1902·92	15	2017·75
441	1446·88	476	1561·71	511	1676·54	546	1791·37	581	1906·20	616	2021·03
42	1450·16	77	1564·99	12	1679·82	47	1794·65	82	1909·48	17	2024·31
43	1453·44	78	1568·27	13	1683·10	48	1797·93	83	1912·76	18	2027·60
44	1456·72	79	1571·55	14	1686·38	49	1801·21	84	1916·05	19	2030·88
45	1460·00	80	1574·83	15	1689·66	50	1804·49	85	1919·33	20	2034·16
446	1463·28	481	1578·11	516	1692·94	551	1807·78	586	1922·61	621	2037·44
47	1466·56	82	1581·39	17	1696·22	52	1811·06	87	1925·89	22	2040·72
48	1469·84	83	1584·67	18	1699·51	53	1814·34	88	1929·17	23	2044·00
49	1473·12	84	1587·96	19	1702·79	54	1817·62	89	1932·45	24	2047·28
50	1476·40	85	1591·23	20	1706·07	55	1820·90	90	1935·73	25	2050·56
451	1479·69	486	1594·52	521	1709·35	556	1824·18	591	1939·01	626	2053·84
52	1482·97	87	1597·80	22	1712·63	57	1827·46	92	1942·29	27	2057·12
53	1486·25	88	1601·08	23	1715·91	58	1830·74	93	1945·57	28	2060·40
54	1489·53	89	1604·36	24	1719·19	59	1834·02	94	1948·85	29	2063·69
55	1492·81	90	1607·64	25	1722·47	60	1837·30	95	1952·13	30	2066·97

TABLE XVI. (*continued*).—CONVERSION OF MÈTRES INTO ENGLISH FEET.

631 to 840.

Mètres	Feet	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.
631	2070·25	666	2185·08	701	2299·91	736	2414·74	771	2529·57	806	2644·40
32	2073·53	67	2188·36	2	2303·19	37	2418·02	72	2532·85	7	2647·69
33	2076·81	68	2191·64	3	2306·47	38	2421·30	73	2536·13	8	2650·97
34	2080·09	69	2194·92	4	2309·75	39	2424·58	74	2539·42	9	2654·25
35	2083·37	70	2198·20	5	2313·03	40	2427·87	75	2542·70	10	2657·53
636	2086·65	671	2201·48	706	2316·31	741	2431·15	776	2545·98	811	2660·81
37	2089·93	72	2204·76	7	2319·60	42	2434·43	77	2549·26	12	2664·09
38	2093·21	73	2208·05	8	2322·88	43	2437·71	78	2552·54	13	2667·37
39	2096·49	74	2211·33	9	2326·16	44	2440·99	79	2555·82	14	2670·65
40	2099·78	75	2214·61	10	2329·44	45	2444·27	80	2559·10	15	2673·93
641	2103·06	676	2217·89	711	2332·72	746	2447·55	781	2562·38	816	2677·21
42	2106·34	77	2221·17	12	2336·00	47	2450·83	82	2565·66	17	2680·49
43	2109·62	78	2224·45	13	2339·28	48	2454·11	83	2568·94	18	2683·78
44	2112·90	79	2227·73	14	2342·56	49	2457·39	84	2572·22	19	2687·06
45	2116·18	80	2231·01	15	2345·84	50	2460·67	85	2575·51	20	2690·34
646	2119·46	681	2234·29	716	2349·12	751	2463·96	786	2578·79	821	2693·62
47	2122·74	82	2237·57	17	2352·40	52	2467·24	87	2582·07	22	2696·90
48	2126·02	83	2240·85	18	2355·69	53	2470·52	88	2585·35	23	2700·18
49	2129·30	84	2244·13	19	2358·97	54	2473·80	89	2588·63	24	2703·46
50	2132·58	85	2247·42	20	2362·25	55	2477·08	90	2591·91	25	2706·74
651	2135·87	686	2250·70	721	2365·53	756	2480·36	791	2595·19	826	2710·02
52	2139·15	87	2253·98	22	2368·81	57	2483·64	92	2598·47	27	2713·30
53	2142·43	88	2257·26	23	2372·09	58	2486·92	93	2601·75	28	2716·58
54	2145·71	89	2260·54	24	2375·37	59	2490·20	94	2605·03	29	2719·87
55	2148·99	90	2263·82	25	2378·65	60	2493·48	95	2608·31	30	2723·15
656	2152·27	691	2267·10	726	2381·93	761	2496·76	796	2611·60	831	2726·43
57	2155·55	92	2270·38	27	2385·21	62	2500·05	97	2614·88	32	2729·71
58	2158·83	93	2273·66	28	2388·49	63	2503·33	98	2618·16	33	2732·99
59	2162·11	94	2276·94	29	2391·78	64	2506·61	99	2621·44	34	2736·27
60	2165·39	95	2280·22	30	2395·06	65	2509·89	800	2624·72	35	2739·55
661	2168·67	696	2283·51	731	2398·34	766	2513·17	801	2628·00	836	2742·83
62	2171·96	97	2286·79	32	2401·62	67	2516·45	2	2631·28	37	2746·11
63	2175·24	98	2290·07	33	2404·90	68	2519·73	3	2634·56	38	2749·39
64	2178·52	99	2293·35	34	2408·18	69	2523·01	4	2637·84	39	2752·67
65	2181·80	700	2296·63	35	2411·46	70	2526·29	5	2641·12	40	2755·96

TABLE XVI. (*continued*).—CONVERSION OF MÈTRES INTO ENGLISH FEET.

841 to 1000.

Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.	Mètres	Feet.
841	2759·24	871	2857·66	901	2956·09	926	3038·11	951	3120·14	976	3202·16
42	2762·52	72	2860·94	2	2959·37	27	3041·39	52	3123·42	77	3205·44
43	2765·80	73	2864·22	3	2962·65	28	3044·67	53	3126·70	78	3208·72
44	2769·08	74	2867·51	4	2965·93	29	3047·96	54	3129·98	79	3212·00
45	2772·36	75	2870·79	5	2969·21	30	3051·24	55	3133·26	80	3215·28
846	2775·64	876	2874·07	906	2972·49	931	3054·52	956	3136·54	981	3218·56
47	2778·92	77	2877·35	7	2975·78	32	3057·80	57	3139·82	82	3221·84
48	2782·20	78	2880·63	8	2979·06	33	3061·08	58	3143·10	83	3225·12
49	2785·48	79	2883·91	9	2982·34	34	3064·36	59	3146·38	84	3228·40
50	2788·76	80	2887·19	10	2985·62	35	3067·64	60	3149·66	85	3231·69
851	2792·05	881	2890·47	911	2988·90	936	3070·92	961	3152·94	986	3234·97
52	2795·33	82	2893·75	12	2992·18	37	3074·20	62	3156·22	87	3238·25
53	2798·61	83	2897·03	13	2995·46	38	3077·48	63	3159·51	88	3241·53
54	2801·89	84	2900·31	14	2998·74	39	3080·76	64	3162·79	89	3244·81
55	2805·17	85	2903·60	15	3002·02	40	3084·05	65	3166·07	90	3248·09
856	2808·45	886	2906·88	916	3005·30	941	3087·33	966	3169·35	991	3251·37
57	2811·73	87	2910·16	17	3008·58	42	3090·61	67	3172·63	92	3254·65
58	2815·01	88	2913·44	18	3011·87	43	3093·89	68	3175·91	93	3257·93
59	2818·29	89	2916·72	19	3015·15	44	3097·17	69	3179·19	94	3261·21
60	2821·57	90	2920·00	20	3018·43	45	3100·45	70	3182·47	95	3264·49
861	2824·85	891	2923·28	921	3021·71	946	3103·73	971	3185·75	996	3267·78
62	2828·14	92	2926·56	22	3024·99	47	3107·01	72	3189·03	97	3271·06
63	2831·42	93	2929·84	23	3028·27	48	3110·29	73	3192·31	98	3274·34
64	2834·70	94	2933·12	24	3031·55	49	3113·57	74	3195·60	99	3277·62
65	2837·98	95	2936·40	25	3034·83	50	3116·85	75	3198·88	1000	3280·90
866	2841·26	896	2939·69								
67	2844·54	97	2942·97								
68	2847·82	98	2946·25								
69	2851·10	99	2949·53								
70	2854·38	900	2952·81								

TABLE XVII.—CONVERSION OF KILOMÈTRES INTO ENGLISH STATUTE MILES.

Kilometres.	English Statute Miles.	Kilomètres.	English Statute Miles.	Kilomètres.	English Statute Miles.	Kilometres.	English Statute Miles.	Kilometres.	English Statute Miles.
1	0·62	21	13·05	41	25·48	61	37·90	81	50·33
2	1·24	22	13·67	42	26·10	62	38·53	82	50·95
3	1·86	23	14·29	43	26·72	63	39·15	83	51·57
4	2·49	24	14·91	44	27·34	64	39·77	84	52·20
5	3·11	25	15·53	45	27·96	65	40·39	85	52·82
6	3·73	26	16·16	46	28·58	66	41·01	86	53·44
7	4·35	27	16·78	47	29·21	67	41·63	87	54·06
8	4·97	28	17·50	48	29·83	68	42·25	88	54·68
9	5·59	29	18·02	49	30·45	69	42·88	89	55·30
10	6·21	30	18·64	50	31·07	70	43·50	90	55·92
11	6·84	31	19·26	51	31·69	71	44·12	91	56·55
12	7·46	32	19·88	52	32·31	72	44·74	92	57·17
13	8·08	33	20·51	53	32·93	73	45·36	93	57·79
14	8·70	34	21·13	54	33·55	74	45·98	94	58·41
15	9·32	35	21·75	55	34·18	75	46·60	95	59·03
16	9·94	36	22·37	56	34·90	76	47·23	96	59·65
17	10·56	37	22·99	57	35·42	77	47·85	97	60·27
18	11·18	38	23·61	58	36·04	78	48·47	98	60·90
19	11·81	39	24·23	59	36·66	79	49·09	99	61·52
20	12·43	40	24·86	60	37·28	80	49·71	100	62·14
100	62·14	300	186·42	500	310·69	700	434·97	900	559·24
200	124·28	400	248·55	600	372·83	800	497·11	1000	621·38
1000	621·38	3000	1864·15	5000	3106·91	7000	4349·68	9000	5592·44
2000	1242·77	4000	2485·53	6000	3728·30	8000	4971·06	10,000	6213·82

TABLE XVIII.—CONVERSION OF RUSSIAN VERSTS INTO ENGLISH STATUTE MILES.

Versts.	English Statute Miles.	Versts.	English Statute Miles.	Versts.	English Statute Miles.	Versts.	English Statute Miles.	Versts.	English Statute Miles.
1	0·66	21	13·92	41	27·18	61	40·44	81	53·69
2	1·33	22	14·58	42	27·84	62	41·10	82	54·36
3	1·99	23	15·25	43	28·50	63	41·76	83	55·02
4	2·65	24	15·91	44	29·17	64	42·42	84	55·68
5	3·31	25	16·57	45	29·83	65	43·09	85	56·34
6	3·98	26	17·23	46	30·49	66	43·75	86	57·01
7	4·64	27	17·90	47	31·16	67	44·41	87	57·67
8	5·30	28	18·56	48	31·82	68	45·08	88	58·33
9	5·97	29	19·22	49	32·48	69	45·74	89	59·00
10	5·63	30	19·89	50	33·14	70	46·40	90	59·66
11	7·29	31	20·55	51	33·81	71	47·06	91	60·32
12	7·95	32	21·21	52	34·47	72	47·73	92	60·98
13	8·62	33	21·88	53	35·13	73	48·39	93	61·65
14	9·28	34	22·54	54	35·80	74	49·05	94	62·31
15	9·94	35	23·20	55	36·46	75	49·72	95	62·97
16	10·61	36	23·86	56	37·12	76	50·38	96	63·64
17	11·27	37	24·53	57	37·78	77	51·04	97	64·30
18	11·93	38	25·19	58	38·45	78	51·70	98	64·96
19	12·59	39	25·85	59	39·11	79	52·37	99	65·63
20	13·26	40	26·52	60	39·77	80	53·03	100	66·29
100	66·29	300	198·86	500	231·44	700	464·02	900	596·59
200	132·58	400	265·15	600	397·73	800	530·30	1000	666·88
1000	662·88	3000	1988·64	5000	3314·39	7000	4640·15	9000	5965·91
2000	1325·76	4000	2651·52	6000	3977·27	8000	5303·03	10,000	6628·79

Table XIX.—For converting Kilogrammes into Pounds Avoirdupois.

Kilogs.	0	1	2	3	4	5	6	7	8	9
0	·000	2·205	4·409	6·614	8·818	11·023	13·228	15·632	17·637	19·842
10	22·046	24·251	26·455	28·660	30·865	33·069	35·274	37·478	39·683	41·888
20	44·092	46·297	48·502	50·706	52·911	55·116	57·320	59·525	61·729	63·934
30	66·139	68·343	70·548	72·753	74·957	77·162	79·366	81·571	83·776	85·980
40	88·185	90·389	92·594	94·799	97·003	99·208	101·413	103·617	105·822	108·026
50	110·231	112·436	114·640	116·845	119·050	121·254	123·549	125·663	127·868	130·073
60	132·277	134·482	136·686	138·891	141·096	143·300	145·505	147·710	149·914	152·119
70	154·323	156·528	158·733	160·937	163·142	165·347	167·551	169·356	171·960	174·165
80	176·370	178·574	180·779	182·984	185·188	187·393	189·597	191·802	194·007	196·211
90	198·416	200·620	202·825	205·030	207·234	209·439	211·644	213·848	216·053	218·258

Table XX.—Foreign Moneys.

With Equivalents in British Currency.

Country.	*Principal Coins.*	Sterling. *s.*	*d.*
Austria	100 new kreuzers = 1 florin	1	8
Belgium	100 centimes = 1 franc	0	9½
Canada, etc.	100 cents = 1 dollar	4	2
China	1600—1700 copper cash = 1 Haikwan tael	4	10¼
Denmark	100 öre = 1 Krone	1	1½
France	100 centimes = 1 franc	0	9½
	Milliard = f. 1000 mills. = £40,000,000.		
Germany	North German or Prussian thaler	3	0
	South German florin	1	8
	Imperial Reichsmark = 100 Pfennige	1	0
	Imperial gold piece of 20 marks	20	0
Greece	100 centimes = 1 franc	0	9½
Holland	100 cents or 20 stivers = 1 florin	1	8
India	192 pie = 64 pice = 16 annas = 1 rupee	about 1	3
	The lac is 100,000 rupees.		
Italy	100 centesimi = 1 lira	0	9½
Norway	100 öre = 1 Krone	1	1½
Portugal	1000 Reis = 1 milrei	4	5
Russia	100 copecs = 1 silver rouble	3	2
Spain	100 centisimos = 1 peseta = 4 reales	0	9½
Sweden	100 öre = 1 Krone	1	1½
Switzerland	100 rappen or centimes = 1 franc	0	9½
Turkey	100 piastre = 1 lira, *variable*	1½*d.* to 0	2¼
United States	100 cents = 1 dollar ($) *in gold*	4	1
	10 dollars = 1 eagle	41	1

TABLE XXI.—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	1 Deg.		2 Deg.		3 Deg.		4 Deg.		5 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	01·0	00·0	01·0	00·0	01·0	00·1	01·0	00·1	01·0	00·1
2	02·0	00·0	02·0	00·1	02·0	00·1	02·0	00·1	02·0	00·2
3	03·0	00·1	03·0	00·1	03·0	00·2	03·0	00·2	03·0	00·3
4	04·0	00·1	04·0	00·1	04·0	00·2	04·0	00·3	04·0	00·3
5	05·0	00·1	05·0	00·2	05·0	00·3	05·0	00·3	05·0	00·4
6	06·0	00·1	06·0	00·2	06·0	00·3	06·0	00·4	06·0	00·5
7	07·0	00·1	07·0	00·2	07·0	00·4	07·0	00·5	07·0	00·6
8	08·0	00·1	08·0	00·3	08·0	00·4	08·0	00·6	08·0	00·7
9	09·0	00·2	09·0	00·3	09·0	00·5	09·0	00·6	09·0	00·8
10	10·0	00·2	10·0	00·3	10·0	00·5	10·0	00·7	10·0	00·9
20	20·0	00·3	20·0	00·7	20·0	01·0	20·0	01·4	19·9	01·7
30	30·0	00·5	30·0	01·0	30·0	01·6	29·9	02·1	29·9	02·6
40	40·0	00·7	40·0	01·4	39·9	02·1	39·9	02·8	39·8	03·5
50	50·0	00·9	50·0	01·7	49·9	02·6	49·9	03·5	49·8	04·4
60	60·0	01·0	60·0	02·1	59·9	03·1	59·9	04·2	59·8	05·2
70	70·0	01·2	70·0	02·4	69·9	03·7	69·8	04·9	69·7	06·1
80	80·0	01·4	80·0	02·8	79·9	04·2	79·8	05·6	79·7	07·0
90	90·0	01·6	89·9	03·1	89·9	04·7	89·8	06·3	89·7	07·8
100	100·0	01·7	99·9	03·5	99·9	05·2	99·8	07·0	99·6	08·7
200	200·0	03·5	199·9	07·0	199·7	10·5	199·5	14·0	199·2	17·4
300	300·0	05·2	299·8	10·5	299·6	15·7	299·3	20·9	298·9	26·1
400	399·9	07·0	399·8	14·0	399·5	20·9	399·0	27·9	398·5	34·9
500	499·9	08·7	499·7	17·5	499·3	26·2	498·8	34·9	498·1	43·6
600	599·9	10·5	599·6	20·9	599·2	31·4	598·5	41·9	597·7	52·3
700	699·9	12·2	699·6	24·4	699·0	36·6	698·3	48·8	697·3	61·0
800	799·9	14·0	799·5	27·9	798·9	41·9	798·1	55·8	797·0	69·7
900	899·9	15·7	899·5	31·4	898·8	47·1	897·8	62·8	896·6	78·4
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
D.	89 Deg.		88 Deg.		87 Deg.		86 Deg.		85 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure*

D.	6 Deg.		7 Deg.		8 Deg.		9 Deg.		10 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	01·0	00·1	01·0	00·1	01·0	00·1	01·0	00·2	01·0	00·2
2	02·0	00·2	02·0	00·2	02·0	00·3	02·0	00·3	02·0	00·3
3	03·0	00·3	03·0	00·4	03·0	00·4	03·0	00·5	03·0	00·5
4	04·0	00·4	04·0	00·5	04·0	00·6	04·0	00·6	03·9	00·7
5	05·0	00·5	05·0	00·6	05·0	00·7	04·9	00·8	04·9	00·9
6	06·0	00·6	06·0	00·7	05·9	00·8	05·9	00·9	05·9	01·0
7	07·0	00·7	06·9	00·9	06·9	01·0	06·9	01·1	06·9	01·2
8	08·0	00·8	07·9	01·0	07·9	01·1	07·9	01·3	07·9	01·4
9	09·0	00·9	08·9	01·1	08·9	01·3	08·9	01·4	08·9	01·6
10	09·9	01·0	09·9	01·2	09·9	01·4	09·9	01·6	09·8	01·7
20	19·9	02·1	19·9	02·4	19·8	02·8	19·8	03·1	19·7	03·5
30	29·8	03·1	29·8	03·7	29·7	04·2	29·6	04·7	29·5	05·2
40	39·8	04·2	39·7	04·9	39·6	05·6	39·5	06·3	39·4	06·9
50	49·7	05·2	49·6	06·1	49·5	07·0	49·4	07·8	49·2	08·7
60	59·7	06·3	59·6	07·3	59·4	08·4	59·3	09·4	59·1	10·4
70	69·6	07·3	69·5	08·5	69·3	09·7	69·1	11·0	68·9	12·2
80	79·6	08·4	79·4	09·7	79·2	11·1	79·0	12·5	78·8	13·9
90	89·5	09·4	89·3	11·0	89·1	12·5	88·9	14·1	88·6	15·6
100	99·5	10·5	99·3	12·2	99·0	13·9	98·8	15·6	98·5	17·4
200	198·9	20·9	198·5	24·4	198·1	27·8	197·5	31·3	197·0	34·7
300	298·4	31·4	297·8	36·6	297·1	41·8	296·3	46·9	295·4	52·1
400	397·8	41·8	397·0	48·7	396·1	55·7	395·1	62·6	393·9	69·5
500	497·3	52·3	496·3	60·9	495·1	69·6	493·8	78·2	492·4	86·8
600	596·7	62·7	595·5	73·1	594·2	83·5	592·6	93·9	590·9	104·2
700	696·2	73·2	694·8	85·3	693·2	97·4	691·4	109·5	689·4	121·6
800	795·6	83·6	794·0	97·5	792·2	111·3	790·2	125·1	787·8	138·9
900	895·1	94·1	893·3	109·7	891·2	125·3	888·9	140·8	886·3	156·3
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
D.	84 Deg.		83 Deg.		82 Deg.		81 Deg.		80 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	11 Deg.		12 Deg.		13 Deg.		14 Deg.		15 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	01·0	00·2	01·0	00·2	01·0	00·2	01·0	00·2	01·0	00·3
2	02·0	00·4	02·0	00·4	01·9	00·4	01·9	00·5	01·9	00·5
3	02·9	00·6	02·9	00·6	02·9	00·7	02·9	00·7	02·9	00·8
4	03·9	00·8	03·9	00·8	03·9	00·9	03·9	01·0	03·9	01·0
5	04·9	01·0	04·9	01·0	04·9	01·1	04·9	01·2	04·8	01·3
6	05·9	01·1	05·9	01·2	05·8	01·3	05·8	01·5	05·8	01·6
7	06·9	01·3	06·8	01·5	06·8	01·6	06·8	01·7	06·8	01·8
8	07·9	01·5	07·8	01·7	07·8	01·8	07·8	01·9	07·7	02·1
9	08·8	01·7	08·8	01·9	08·8	02·0	08·7	02·2	08·7	02·3
10	09·8	01·9	09·8	02·1	09·7	02·2	09·7	02·4	09·7	02·6
20	19·6	03·8	19·6	04·2	19·5	04·5	19·4	04·8	19·3	05·2
30	29·4	05·7	29·3	06·2	29·2	06·7	29·1	07·3	29·0	07·8
40	39·3	07·6	39·1	08·3	39·0	09·0	38·8	09·7	38·6	10·4
50	49·1	09·5	48·9	10·4	48·7	11·2	48·5	12·1	48·3	12·9
60	58·9	11·4	58·7	12·5	58·5	13·5	58·2	14·5	58·0	15·5
70	68·7	13·4	68·5	14·6	68·2	15·7	67·9	16·9	67·6	18·1
80	78·5	15·3	78·3	16·6	77·9	18·0	77·6	19·4	77·3	20·7
90	88·3	17·2	88·0	18·7	87·7	20·2	87·3	21·8	86·9	23·3
100	98·2	19·1	97·8	20·8	97·4	22·5	97·0	24·2	96·6	25·9
200	196·3	38·2	195·6	41·6	194·9	45·0	194·1	48·4	193·2	51·8
300	294·5	57·2	293·4	62·4	292·3	67·5	291·1	72·6	289·8	77·6
400	392·7	76·3	391·3	83·2	389·7	90·0	388·1	96·8	386·4	103·5
500	490·8	95·4	489·1	104·0	487·2	112·5	485·1	121·0	483·0	129·4
600	589·0	114·5	586·9	124·7	584·6	135·0	582·2	145·2	579·6	155·3
700	687·1	133·6	684·7	145·5	682·1	157·5	679·2	169·3	676·1	181·2
800	785·3	152·6	782·5	166·3	779·5	180·0	776·2	193·5	772·7	207·1
900	883·3	171·7	880·3	187·1	876·9	202·5	873·3	217·7	869·3	232·9
D.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	79 Deg.		78 Deg.		77 Deg.		76 Deg.		75 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	16 Deg.		17 Deg.		18 Deg.		19 Deg.		20 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	01·0	00·3	01·0	00·3	01·0	00·3	00·9	00·3	00·9	00·3
2	01·9	00·6	01·9	00·6	01·9	00·6	01·9	00·7	01·9	00·7
3	02·9	00·8	02·9	00·9	02·9	00·9	02·8	01·0	02·8	01·0
4	03·8	01·1	03·8	01·2	03·8	01·2	03·8	01·3	03·8	01·4
5	04·8	01·4	04·8	01·5	04·8	01·5	04·7	01·6	04·7	01·7
6	05·8	01·7	05·7	01·8	05·7	01·9	05·7	02·0	05·6	02·1
7	06·7	01·9	06·7	02·0	06·7	02·2	06·6	02·3	06·6	02·4
8	07·7	02·2	07·7	02·3	07·6	02·5	07·6	02·6	07·5	02·7
9	08·7	02·5	08·6	02·6	08·6	02·8	08·5	02·9	08·5	03·1
10	09·6	02·8	09·6	02·9	09·5	03·1	09·5	03·3	09·4	03·4
20	19·2	05·5	19·1	05·8	19·0	06·2	18·9	06·5	18·8	06·8
30	28·8	08·3	28·7	08·8	28·5	09·3	28·4	09·8	28·2	10·3
40	38·5	11·0	38·3	11·7	38·0	12·4	37·8	13·0	37·6	13·7
50	48·1	13·8	47·8	14·6	47·6	15·5	47·3	16·3	47·0	17·1
60	57·7	16·5	57·4	17·5	57·1	18·5	56·7	19·5	56·4	20·5
70	67·3	19·3	66·9	20·5	66·6	21·6	66·2	22·8	65·8	23·9
80	76·9	22·1	76·5	23·4	76·1	24·7	75·6	26·0	75·2	27·4
90	86·5	24·8	86·1	26·3	85·6	27·8	85·1	29·3	84·6	30·8
100	96·1	27·6	95·6	29·2	95·1	30·9	94·6	32·6	94·0	34·2
200	192·3	55·1	191·3	58·5	190·2	61·8	189·1	65·1	187·9	68·4
300	288·4	82·7	286·9	87·7	285·3	92·7	283·7	97·7	281·9	102·6
400	384·5	110·3	382·5	116·9	380·4	123·6	378·2	130·2	375·9	136 8
500	480·6	137·8	478·2	146·2	475·5	154·5	472·8	162·8	469·8	171·0
600	576·8	165·4	573·8	175·4	570·6	185·4	567·3	195·3	563·8	205·2
700	672·9	192 9	669·4	204·7	665·7	216·3	661·9	227·9	657·8	239·4
800	769·0	220·5	765·0	233·9	760·8	247·2	756·4	260·5	751·8	273·6
900	865·1	248·1	860·7	263·1	856·0	278·1	851·0	293·0	845·7	307·8
D.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	74 Deg.		73 Deg.		72 Deg.		71 Deg.		70 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	21 Deg.		22 Deg.		23 Deg.		24 Deg.		25 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	00·9	00·4	00·9	00·4	00·9	00·4	00·9	00·4	00·9	00·4
2	01·9	00·7	01·9	00·7	01·8	00·8	01·8	00·8	01·8	00·8
3	02·8	01·1	02·8	01·1	02·8	01·2	02·7	01·2	02·7	01·3
4	03·7	01·4	03·7	01·5	03·7	01·6	03·7	01·6	03·6	01·7
5	04·7	01·8	04·6	01·9	04·6	02·0	04·6	02·0	04·5	02·1
6	05·6	02·2	05·6	02·2	05·5	02·3	05·5	02·4	05·4	02·5
7	06·5	02·5	06·5	02·6	06·4	02·7	06·4	02·8	06·3	03·0
8	07·5	02·9	07·4	03·0	07·4	03·1	07·3	03·3	07·3	03·4
9	08·4	03·2	08·3	03·4	08·3	03·5	08·2	03·7	08·2	03·8
10	09·3	03·6	09·3	03·7	09·2	03·9	09·1	04·1	09·1	04·2
20	18·7	07·2	18·5	07·5	18·4	07·8	18·3	08·1	18·1	08·5
30	28·0	10·8	27·8	11·2	27·6	11·7	27·4	12·2	27·2	12·7
40	37·3	14·3	37·1	15·0	36·8	15·6	36·5	16·3	36·3	16·9
50	46·7	17·9	46·4	18·7	46·0	19·5	45·7	20·3	45·3	21·1
60	56·0	21·5	55·6	22·5	55·2	23·4	54·8	24·4	54·4	25·4
70	65·4	25·1	64·9	26·2	64·4	27·4	63·9	28·5	63·4	29·6
80	74·7	28·7	74·2	30·0	73·6	31·3	73·1	32·5	72·5	33·8
90	84·0	32·3	83·4	33·7	82·8	35·2	82·2	36·6	81·6	38·0
100	93·4	35·8	92·7	37 5	92·1	39·1	91·4	40·7	90·6	42·3
200	186·7	71·7	185·4	74·9	184·1	78·1	182·7	81·3	181·3	84·5
300	280·1	107·5	278·2	112·4	276·2	117·2	274·1	122·0	271·9	126·8
400	373·4	143·3	370·9	149·8	368·2	156·3	365·4	162·7	362·5	169·0
500	466·8	179·2	463·6	187·3	460·3	195·4	456·8	203·4	453·2	211·3
600	560·1	215·0	556·3	224·8	552·3	234·4	548·1	244·0	543·8	253·6
700	653·5	250·9	649·0	262·2	644·4	273·5	639·5	284·7	634·4	295·8
800	746·9	286·7	741·7	299·7	736·4	312·6	430·8	325·4	725·0	338·1
900	840·2	322·5	834·5	337·1	828·5	351·7	822·2	366·1	815·7	380·4
D.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	69 Deg.		68 Deg.		67 Deg.		66 Deg.		65 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	26 Deg.		27 Deg.		28 Deg.		29 Deg.		30 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	00·9	00·4	00·9	00·5	00·9	00·5	00·9	00·5	00·9	00·5
2	01·8	00·9	01·8	00·9	01·8	00·9	01·7	01·0	01·7	01·0
3	02·7	01·3	02·7	01·4	02·6	01·4	02·6	01·5	02·6	01·5
4	03·6	01·8	03·6	01·8	03·5	01·9	03·5	01·9	03·5	02·0
5	04·5	02·2	04·5	02·3	04·4	02·3	04·4	02·4	04·3	02·5
6	05·4	02·6	05·3	02·7	05·3	02·8	05·2	02·9	05·2	03·0
7	06·3	03·1	06·2	03·2	06·2	03·3	06·1	03·4	06·1	03·5
8	07·2	03·5	07·1	03·6	07·1	03·8	07·0	03·9	06·9	04·0
9	08·1	03·9	08·0	04·1	07·9	04·2	07·9	04·4	07·8	04·5
10	09·0	04·4	08·9	04·5	08·8	04·7	08·7	04·8	08·7	05·0
20	18·0	08·8	17·8	09·1	17·7	09·4	17·5	09·7	17·3	10·0
30	27·0	13·2	26·7	13·6	26·5	14·1	26·2	14·5	26·0	15·0
40	36·0	17·5	35·6	18·2	35·3	18·8	35·0	19·4	34·6	20·0
50	44·9	21·9	44·6	22·7	44·1	23·5	43·7	24·2	43·3	25·0
60	53·9	26·3	53·5	27·2	53·0	28·2	52·5	29·1	52·0	30·0
70	62·9	30·7	62·4	31·8	61·8	32·9	61·2	33·9	60·6	35·0
80	71·9	35·1	71·3	36·3	70·6	37·6	70·0	38·8	69·3	40·0
90	80·9	39·5	80·2	40·9	79·5	42·3	78·7	43·6	77·9	45·0
100	89·9	43·8	89·1	45·4	88·3	46·9	87·5	48·5	86·6	50·0
200	179·8	87·7	178·2	90·8	176·6	93·9	174·9	97·0	173·2	100·0
300	269·6	131·5	267·3	136·2	264·9	140·8	262·4	145·4	259·8	150·0
400	359·5	175·3	356·4	181·6	353·2	187·8	349·8	193·9	346·4	200·0
500	449·4	219·2	445·5	227·0	441·5	234·7	437·3	242·4	433·0	250·0
600	539·3	263·0	534·6	272·4	529·8	281·7	524·8	290·9	519·6	300·0
700	629·2	306·9	623·7	317·8	618·1	328·6	612·2	339·4	606·2	350·0
800	719·0	350·7	712·8	363·2	706·4	375·6	699·7	387·8	692·8	400·0
900	808·9	394·5	801·9	408·6	794·7	422·5	787·2	436·3	779·4	450·0
D.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	64 Deg.		63 Deg.		62 Deg.		61 Deg.		60 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	31 Deg.		32 Deg.		33 Deg.		34 Deg.		35 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	00·9	00·5	00·8	00·5	00·8	00·5	00·8	00·6	00·8	00·6
2	01·7	01·0	01·7	01·1	01·7	01·1	01·7	01·1	01·6	01·1
3	02·6	01·5	02·5	01·6	02·5	01·6	02·5	01·7	02·5	01·7
4	03·4	02·1	03·4	02·1	03·4	02·2	03·3	02·2	03·3	02·3
5	04·3	02·6	04·2	02·6	04·2	02·7	04·1	02·8	04·1	02·9
6	05·1	03·1	05·1	03·2	05·0	03·3	05·0	03·4	04·9	03·4
7	06·0	03·6	05·9	03·7	05·9	03·8	05·8	03·9	05·7	04·0
8	06·9	04·1	06·8	04·2	06·7	04·4	06·6	04·5	06·6	04·6
9	07·7	04·6	07·6	04·8	07·5	04·9	07·5	05·0	07·4	05·2
10	08·6	05·2	08·5	05·3	08·4	05·4	08·3	05·6	08·2	05·7
20	17·1	10·3	17·0	10·6	16·8	10·9	16·6	11·2	16·4	11·5
30	25·7	15·5	25·4	15·9	25·2	16·3	24·9	16·8	24·6	17·2
40	34·3	20·6	33·9	21·2	33·5	21·8	33·2	22·4	32·8	22·9
50	42·9	25·8	42·4	26·5	41·9	27·2	41·5	28·0	41·0	28·7
60	51·4	30·9	50·9	31·8	50·3	32·7	49·7	33·6	49·1	34·4
70	60·0	36·1	59·4	37·1	58·7	38·1	58·0	39·1	57·3	40·2
80	68·6	41·2	67·8	42·4	67·1	43·6	66·3	44·7	65·5	45·9
90	77·1	46·4	76·3	47·7	75·5	49·0	74·6	50·3	73·7	51·6
100	85·7	51·5	84·8	53·0	83·9	54·5	82·9	55·9	81·9	57·4
200	171·4	103·0	169·6	106·0	167·7	108·9	165·8	111·8	163·8	114·7
300	257·2	154·5	254·4	159·0	251·6	163·4	248·7	167·8	245·7	172·1
400	342·9	206·0	339·2	212·0	335·5	217·9	331·6	223·7	327·7	229·4
500	428·6	257·5	424·0	265·0	419·3	272·3	414·5	279·6	409·6	286·8
600	514·3	309·0	508·8	318·0	503·2	326·8	497·4	335·5	491·5	344·1
700	600·0	360·5	593·6	370·9	587·1	381·2	580·3	391·4	573·4	401·5
800	685·7	412·0	678·4	423·9	670·9	435·7	663·2	447·4	655·3	458·9
900	771·5	463·5	763·2	476·9	754·8	490·2	746·1	503·3	737·2	516·2
D.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	59 Deg.		58 Deg.		57 Deg.		56 Deg.		55 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	36 Deg.		37 Deg.		38 Deg.		39 Deg.		40 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	00·8	00·6	00·8	00·6	00·8	00·6	00·8	00·6	00·8	00·6
2	01·6	01·2	01·6	01·2	01·6	01·2	01·6	01·3	01·5	01·3
3	02·4	01·8	02·4	01·8	02·4	01·8	02·3	01·9	02·3	01·9
4	03·2	02·4	03·2	02·4	03·2	02·5	03·1	02·5	03·1	02·6
5	04·0	02·9	04·0	03·0	03·9	03·1	03·9	03·1	03·8	03·2
6	04·9	03·5	04·8	03·6	04·7	03·7	04·7	03·8	04·6	03·9
7	05·7	04·1	05·6	04·2	05·5	04·3	05·4	04·4	05·4	04·5
8	06·5	04·7	06·4	04·8	06·3	04·9	06·2	05·0	06·1	05·1
9	07·3	05·3	07·2	05·4	07·1	05·5	07·0	05·7	06·9	05·8
10	08·1	05·9	08·0	06·0	07·9	06·2	07·8	06·3	07·7	06·4
20	16·2	11·8	16·0	12·0	15·8	12·3	15·5	12·6	15·3	12·9
30	24·3	17·6	24·0	18·1	23·6	18·5	23·3	18·9	23·0	19·3
40	32·4	23·5	31·9	24·1	31·5	24·6	31·1	25·2	30·6	25·7
50	40·5	29·4	39·9	30·1	39·4	30·8	38·9	31·5	38·3	32·1
60	48·5	35·3	47·9	36·1	47·3	36·9	46·6	37·8	46·0	38·6
70	56·6	41·1	55·9	42·1	55·2	43·1	54·4	44·1	53·6	45·0
80	64·7	47·0	63·9	48·1	63·0	49·3	62·2	50·3	61·3	51·4
90	72·8	52·9	71·9	54·2	70·9	55·4	69·9	56·6	68·9	57·9
100	80·9	58·8	79·9	60·2	78·8	61·6	77·7	62·9	76·6	64·3
200	161·8	117·6	159·7	120·4	157·6	123·1	155·4	125·9	153·2	128·6
300	242·7	176·3	239·6	180·5	236·4	184·7	233·1	188·8	229·8	192·8
400	323·6	235·1	319·5	240·7	315·2	246·3	310·9	251·7	306·4	257·1
500	404·5	293·9	399·3	300·9	394·0	307·8	388·6	314·7	383·0	321·4
600	485·4	352·7	479·2	361·1	472·8	369·4	466·3	377·6	459·6	385·7
700	566·3	411·4	559·0	421·3	551·6	431·0	544·0	440·5	536·2	450·0
800	647·2	470·2	638·9	481·5	630·4	492·5	621·7	503·5	612·8	514·2
900	728·1	529·0	718·8	541·6	709·2	554·1	699·4	566·4	689·4	578·5
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
D.	54 Deg.		53 Deg.		52 Deg.		51 Deg.		50 Deg.	

TABLE XXI. (*continued*).—TRAVERSE TABLE: *Difference of Latitude and Departure.*

D.	41 Deg.		42 Deg.		43 Deg.		44 Deg.		45 Deg.	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	00·8	00·7	00·7	00·7	00·7	00·7	00·7	00·7	00·7	00·7
2	01·5	01·3	01·5	01·3	01·5	01·4	01·4	01·4	01·4	01·4
3	02·3	02·0	02·2	02·0	02·2	02·0	02·2	02·1	02·1	02·1
4	03·0	02·6	03·0	02·7	02·9	02·7	02·9	02·8	02·8	02·8
5	03·8	03·3	03·7	03·3	03·7	03·4	03·6	03·5	03·5	03·5
6	04·5	03·9	04·5	04·0	04·4	04·1	04·3	04·2	04·2	04·2
7	05·3	04·6	05·2	04·7	05·1	04·8	05·0	04·9	04·9	04·9
8	06·0	05·2	05·9	05·4	05·9	05·5	05·8	05·6	05·7	05·7
9	06·8	05·9	06·7	06·0	06·6	06·1	06·5	06·3	06·4	06·4
10	07·5	06·6	07·4	06·7	07·3	06·8	07·2	06·9	07·1	07·1
20	15·1	13·1	14·9	13·4	14·6	13·6	14·4	13·9	14·1	14·1
30	22·6	19·7	22·3	20·1	21·9	20·5	21·6	20·8	21·2	21·2
40	30·2	26·2	29·7	26·8	29·3	27·3	28·8	27·8	28·3	28·3
50	37·7	32·8	37·2	33·5	36·6	34·1	36·0	34·7	35·4	35·4
60	45·3	39·4	44·6	40·1	43·9	40·9	43·2	41·7	42·4	42·4
70	52·8	45·9	52·0	46·8	51·2	47·7	50·4	48·6	49·5	49·5
80	60·4	52·5	59·5	53·5	58·5	54·6	57·5	55·6	56·6	56·6
90	67·9	59·0	66·9	60·2	65·8	61·4	64·7	62·5	63·6	63·6
100	75·5	65·6	74·3	66·9	73·1	68·2	71·9	69·5	70·7	70·7
200	150·9	131·2	148·6	133·8	146·3	136·4	143·9	138·9	141·4	141·4
300	226·4	196·8	222·9	200·7	219·4	204·6	215·8	208·4	212·1	212·1
400	301·9	262·4	297·3	267·7	292·5	272·8	287·7	277·9	282·8	282·8
500	377·4	328·0	371·6	334·6	365·7	341·0	359·7	347·3	353·6	353·6
600	452·8	393·6	445·9	401·5	438·8	409·2	431·6	416·8	424·3	424·3
700	528·3	459·2	520·2	468·4	511·9	477·4	503·5	486·3	495·0	495·0
800	603·8	524·8	594·5	535·3	585·1	545·6	575·5	555·8	565·7	565·7
900	679·2	590·5	668·8	602·2	658·2	613·8	647·4	625·2	636·4	636·4
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
D.	49 Deg.		48 Deg.		47 Deg.		46 Deg.		45 Deg.	

TABLE XXII.—NATURAL SINES, TANGENTS, SECANTS, ETC.

Deg.	Sine.	Cosec.	Tan.	Cotan.	Secant.	Cosin.	
0	0·00	infinite.	0·00	infinite.	1·00000	1·00000	90
1	0·01745	57·2986	0·01745	57·2899	1·00015	0·99984	89
2	0·03489	28·6537	0·03492	28·6362	1·00060	0·99939	88
3	0·05233	19·1073	0·05240	19·0811	1·00137	0·99862	87
4	0·06975	14·3355	0·06992	14·3006	1·00244	0·99756	86
5	0·08715	11·4737	0·08748	11·4300	1·00381	0·99619	85
6	0·10452	9·5667	0·10510	9·5143	1·00550	0·99452	84
7	0·12186	8·2055	0·12278	8·1443	1·00750	0·99254	83
8	0·13917	7·1852	0·14054	7·1153	1·00982	0·99026	82
9	0·15643	6·3924	0·15838	6·3137	1·01246	0·98768	81
10	0·17364	5·7587	0·17632	5·6712	1·01542	0·98480	80
11	0·19080	5·2408	0·19438	5·1445	1·01871	0·98162	79
12	0·20791	4·8097	0·21255	4·7046	1·02234	0·97814	78
13	0·22495	4·4454	0·23086	4·3314	1·02630	0·97437	77
14	0·24192	4·1335	0·24932	4·0107	1·03061	0·97029	76
15	0·25881	3·8637	0·26794	3·7320	1·03527	0·96592	75
16	0·27563	3·6279	0·28674	3·4874	1·04029	0·96126	74
17	0·29237	3·4203	0·30573	3·2708	1·04569	0·95630	73
18	0·30901	3·2360	0·32491	3·0776	1·05146	0·95105	72
19	0·32556	3·0715	0·34432	2·9042	1·05762	0·94551	71
20	0·34202	2·9238	0·36397	2·7474	1·06417	0·93969	70
21	0·35836	2·7904	0·38386	2·6050	1·07114	0·93358	69
22	0·37460	2·6694	0·40402	2·4750	1·07853	0·92781	68
23	0·39073	2·5593	0·42447	2·3558	1·08636	0·92059	67
24	0·40673	2·4585	0·44522	2·2460	1·09463	0·91354	66
25	0·42261	2·3662	0·46630	2·1445	1·10337	0·90630	65
26	0·43837	2·2811	0·48773	2·0503	1·11260	0·89879	64
27	0·45399	2·2026	0·50952	1·9626	1·12232	0·89100	63
28	0·46947	2·1300	0·53170	1·8807	1·13257	0·88294	62
29	0·48480	2·0626	0·55430	1·8040	1·14335	0·87461	61
30	0·50000	2·0000	0·57735	1·7320	1·15470	0·86602	60
31	0·51503	1·9416	0·60086	1·6642	1·16663	0·85716	59
32	0·52991	1·8870	0·62486	1·6003	1·17917	0·84804	58
33	0·54463	1·8360	0·64940	1·5398	1·19236	0·83867	57
34	0·55919	1·7882	0·67450	1·4825	1·20621	0·82903	56
35	0·57357	1·7434	0·70020	1·4281	1·22077	0·81915	55
36	0·58778	1·7013	0·72654	1·3763	1·23606	0·80901	54
37	0·60181	1·6616	0·75355	1·3270	1·25213	0·79863	53
38	0·61566	1·6242	0·78128	1·2799	1·26901	0·78801	52
39	0·62932	1·5890	0·80978	1·2348	1·28675	0·77714	51
40	0·64278	1·5557	0·83909	1·1917	1·30540	0·76604	50
41	0·65605	1·5242	0·86928	1·1503	1·32501	0·75470	49
42	0·66913	1·4944	0·90040	1·1106	1·34563	0·74314	48
43	0·68199	1·4662	0·93251	1·0723	1·36732	0·73135	47
44	0·69465	1·4395	0·96568	1·0355	1·39016	0·71933	46
45	0·70710	1·4142	1·00000	1·0000	1·41421	0·70710	45
	Cosin.	Secant.	Cotan.	Tan.	Cosec.	Sine.	Deg.

Table XXIII.

T′ = Approx. Long. in Time.		B = Mean of Second Differences.											
		1^m	2^m	3^m	4^m	5^m	6^m	7^m	8^m	9^m	10^m	11^m	12^m
H. M.	H. M.	″	″	″	″	″	″	″	″	″	″	″	″
0. 0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.10	11.50	0.4	0.8	1.2	1.6	2.1	2.5	2.9	3.3	3.7	4.1	4.5	4.9
0.20	11.40	0.8	1.6	2.4	3.2	4.1	4.9	5.7	6.5	7.3	8.1	8.9	9.7
0.30	11.30	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4
0.40	11.20	1.6	3.1	4.7	6.3	7.9	9.4	11.0	12.6	14.2	15.7	17.3	18.9
0.50	11.10	1.9	3.9	5.8	7.8	9.7	11.6	13.6	15.5	17.4	19.4	21.3	23.3
1. 0	11. 0	2.3	4.6	6.9	9.2	11.5	13.7	16.0	18.3	20.6	22.9	25.2	27.5
1.10	10.50	2.6	5.3	7.9	10.5	13.2	15.8	18.4	21.1	23.7	26.3	29.0	31.6
1.20	10.40	3.0	5.9	8.9	11.9	14.8	17.8	20.7	23.7	26.7	29.6	32.6	35.6
1.30	10.30	3.3	6.6	9.8	13.1	16.4	19.7	23.0	26.2	29.5	32.8	36.1	39.4
1.40	10.20	3.6	7.2	10.8	14.4	17.9	21.5	25.1	28.7	32.3	35.9	39.5	43.1
1.50	10.10	3.9	7.8	11.6	15.5	19.4	23.3	27.2	31.1	34.9	38.8	42.7	46.6
2. 0	10. 0	4.2	8.3	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0
2.10	9.50	4.4	8.9	13.3	17.8	22.2	26.6	31.1	35.5	39.9	44.4	48.8	53.3
2.20	9.40	4.7	9.4	14.1	18.8	23.5	28.2	32.9	37.6	42.3	47.0	51.7	56.4
2.30	9.30	4.9	9.9	14.8	19.8	24.7	29.7	34.6	39.6	44.5	49.5	54.4	59.4
2.40	9.20	5.2	10.4	15.6	20.7	25.9	31.1	36.3	41.5	46.7	51.9	57.0	62.2
2.50	9.10	5.4	10.8	16.2	21.6	27.1	32.5	37.9	43.3	48.7	54.1	49.5	64.9
3. 0	9. 0	5.6	11.2	16.9	22.5	28.1	33.7	39.4	45.0	50.6	56.2	61.9	67.5
3.10	8.50	5.8	11.7	17.5	23.3	29.1	35.0	40.8	46.6	52.4	58.3	64.1	69.9
3.20	8.40	6.0	12.0	18.1	24.1	30.1	36.1	42.1	48.1	54.2	60.2	66.2	72.2
3.30	8.30	6.2	12.4	18.6	24.8	31.0	37.2	43.4	49.6	55.8	62.0	68.2	74.4
3.40	8.20	6.4	12.7	19.1	25.5	31.8	38.2	44.6	50.9	57.3	63.7	70.0	76.4
3.50	8.10	6.5	13.0	19.6	26.1	32.6	39.1	45.7	52.2	58.7	65.2	71.7	78.3
4. 0	8. 0	6.7	13.3	20.0	26.7	33.3	40.0	46.7	53.3	60.0	66.7	73.3	80.0
4.20	7.40	6.9	13.8	20.8	27.7	34.6	41.5	48.4	55.4	62.3	69.2	76.1	83.1
4.40	7.20	7.1	14.3	21.4	28.5	35.6	42.8	49.9	57.0	64.2	71.3	78.4	85.6
5. 0	7. 0	7.3	14.6	21.9	29.2	36.5	43.7	51.0	58.3	65.6	72.9	80.2	87.5
5.20	6.40	7.4	14.8	22.2	29.6	37.0	44.4	51.9	59.3	66.7	74.1	81.5	88.9
5.40	6.20	7.5	15.0	22.4	29.9	37.4	44.9	52.3	59.8	67.3	74.8	82.2	89.7
6. 0	6. 0	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0

Table XXIII. (*continued*).

T′ = Approx. Long. in Time.		B = Mean of Second Differences.													
		10sec	20sec	30sec	40sec	50sec	1sec	2sec	3sec	4sec	5sec	6sec	7sec	8sec	9sec
H. M.	H. M.	″	″	″	″	″	″	″	″	″	″	″	″	″	″
0. 0	12. 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.10	11.50	0.1	0.1	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
0.20	11.40	0.1	0.3	0.4	0.5	0.7	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
0.30	11.30	0.2	0.4	0.6	0.8	1.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2
0.40	11.20	0.3	0.5	0.8	1.0	1.3	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
0.50	11.10	0.3	0.6	1.0	1.3	1.6	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3
1. 0	11. 0	0.4	0.8	1.1	1.5	1.9	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
1.10	10.50	0.4	0.9	1.3	1.8	2.2	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4
1.20	10.40	0.5	1.0	1.5	2.0	2.5	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4
1.30	10.30	0.5	1.1	1.6	2.2	2.7	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
1.40	10.20	0.6	1.2	1.8	2.4	3.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5
1.50	10.10	0.6	1.3	1.9	2.6	3.2	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6
2. 0	10. 0	0.7	1.4	2.1	2.8	3.5	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6
2.10	9.50	0.7	1.5	2.2	3.0	3.7	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7
2.20	9.40	0.8	1.6	2.3	3.1	3.9	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7
2.30	9.30	0.8	1.6	2.5	3.3	4.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.7
2.40	9.20	0.9	1.7	2.6	3.5	4.3	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8
2.50	9.10	0.9	1.8	2.7	3.6	4.5	0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8
3. 0	9. 0	0.9	1.9	2.8	3.7	4.7	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8
3.10	8.50	1.0	1.9	2.9	3.9	4.9	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3.20	8.40	1.0	2.0	3.0	4.0	5.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3.30	8.30	1.0	2.1	3.1	4.1	5.2	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3.40	8.20	1.1	2.1	3.2	4.2	5.3	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0
3.50	8.10	1.1	2.2	3.3	4.3	5.4	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.0
4. 0	8. 0	1.1	2.2	3.3	4.4	5.6	0.1	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0
4.20	7.40	1.2	2.3	3.5	4.6	5.8	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1.0
4.40	7.20	1.2	2.4	3.6	4.8	5.9	0.1	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.1
5. 0	7. 0	1.2	2.4	3.6	4.9	6.1	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1
6. 0	6. 0	1.2	2.5	3.7	5.0	6.2	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1

TABLE XXIV.—ANGLES SUBTENDED BY A 10-FT. ROD AT DISTANCES FROM 50 TO 1500 FEET.

Feet.	Angle.			Feet.	Angle.			Feet.	Angle.			Feet.	Angle.			Feet.	Angle.		
	°	′	″		°	′	″		°	′	″		°	′	″		°	′	″
50	11	27	33	97	5	54	24	144	3	58	44	191	2	59	59	276	2	4	33
51	11	14	4	98	5	50	47	145	3	57	5	192	2	59	3	278	2	3	39
52	11	1	7	99	5	47	15	146	3	55	28	193	2	58	7	280	2	2	46
53	10	48	38	100	5	43	46	147	3	53	51	194	2	57	12	282	2	1	54
54	10	36	34	101	5	40	27	148	3	52	17	195	2	56	18	284	2	1	2
55	10	25	3	102	5	37	32	149	3	50	43	196	2	55	23	286	2	0	12
56	10	13	53	103	5	33	45	150	3	49	11	197	2	54	36	288	1	59	22
57	10	3	7	104	5	30	33	151	3	47	38	198	2	53	37	290	1	58	32
58	9	52	43	105	5	27	24	152	3	46	10	199	2	52	49	292	1	57	44
59	9	42	40	106	5	24	19	153	3	44	41	200	2	51	53	294	1	56	55
60	9	32	58	107	5	21	17	154	3	43	12	202	2	50	13	296	1	56	8
61	9	23	34	108	5	18	17	155	3	41	47	204	2	48	46	298	1	55	21
62	9	14	28	109	5	15	23	156	3	40	22	206	2	46	47	300	1	54	35
63	9	5	42	110	5	12	31	157	3	38	58	208	2	45	16	302	1	53	49
64	8	57	9	111	5	9	42	158	3	37	34	210	2	43	42	304	1	53	5
65	8	48	53	112	5	6	56	159	3	36	12	212	2	42	9	306	1	52	20
66	8	40	52	113	5	4	13	160	3	34	51	214	2	40	38	308	1	51	36
67	8	33	6	114	5	1	33	161	3	33	31	216	2	39	8	310	1	50	53
68	8	25	33	115	4	58	56	162	3	32	12	218	2	37	41	312	1	50	11
69	8	18	13	116	4	56	21	163	3	30	54	220	2	36	16	314	1	49	29
70	8	11	7	117	4	53	50	164	3	29	37	222	2	34	51	316	1	48	47
71	8	4	11	118	4	51	20	165	3	28	21	224	2	33	28	318	1	48	6
72	7	57	28	119	4	48	57	166	3	27	5	226	2	32	6	320	1	47	25
73	7	50	56	120	4	46	29	167	3	25	52	228	2	30	46	322	1	46	45
74	7	44	34	121	4	44	6	168	3	24	38	230	2	29	28	324	1	46	6
75	7	38	22	122	4	41	47	169	3	23	25	232	2	28	10	326	1	45	27
76	7	32	20	123	4	39	29	170	3	22	13	234	2	26	55	328	1	44	48
77	7	26	28	124	4	37	14	171	3	21	2	236	2	25	40	330	1	44	10
78	7	20	44	125	4	35	1	172	3	19	52	238	2	24	28	332	1	43	32
79	7	15	9	126	4	32	51	173	3	18	13	240	2	23	14	334	1	42	56
80	7	9	43	127	4	30	41	174	3	17	34	242	2	22	3	336	1	42	19
81	7	4	25	128	4	28	34	175	3	16	26	244	2	20	23	338	1	41	42
82	6	59	14	129	4	26	29	176	3	15	19	246	2	19	44	340	1	41	6
83	6	54	11	130	4	24	26	177	3	14	13	248	2	18	37	342	1	40	31
84	6	49	16	131	4	22	25	178	3	13	8	250	2	17	30	344	1	39	56
85	6	44	26	132	4	20	26	179	3	12	3	252	2	16	25	346	1	39	6
86	6	39	44	133	4	18	28	180	3	10	59	254	2	15	20	348	1	38	47
87	6	35	8	134	4	16	33	181	3	9	56	256	2	14	17	350	1	38	13
88	6	30	39	135	4	14	39	182	3	8	53	258	2	13	15	352	1	37	39
89	6	26	16	136	4	12	46	183	3	7	51	260	2	12	13	354	1	37	6
90	6	21	59	137	4	10	56	184	3	6	50	262	2	11	12	356	1	36	34
91	6	17	46	138	4	9	6	185	3	5	49	264	2	10	13	358	1	36	1
92	6	13	40	139	4	7	16	186	3	4	49	266	2	9	14	360	1	35	29
93	6	9	39	140	4	5	33	187	3	3	50	268	2	8	16	362	1	34	58
94	6	5	43	141	4	3	48	188	3	2	51	270	2	7	19	364	1	34	26
95	6	1	52	142	4	2	5	189	3	1	53	272	2	6	23	366	1	33	55
96	5	58	6	143	4	0	24	190	3	0	56	274	2	5	28	368	1	33	25

TABLE XXIV. (*continued*).—ANGLES SUBTENDED BY A 10-FT. ROD AT DISTANCES FROM 50 TO 1500 FEET.

Feet.	Angle.			Feet.	Angle.			Feet.	Angle.			Feet.	Angle.			Feet.	Angle.		
	°	′	″		°	′	″		°	′	″		°	′	″		°	′	″
370	1	32	54	495	1	9	27	666	0	51	37	942	0	36	30	1224	0	28	5
372	1	32	24	498	1	9	2	672	0	51	9	948	0	36	16	1230	0	27	57
374	1	31	55	501	1	8	37	678	0	50	42	954	0	36	2	1236	0	27	49
376	1	31	25	504	1	8	12	684	0	50	15	960	0	35	48	1242	0	27	41
378	1	30	56	507	1	7	48	690	0	49	49	966	0	35	35	1248	0	27	32
380	1	30	28	510	1	7	24	696	0	49	23	972	0	35	22	1254	0	27	25
382	1	29	59	513	1	7	1	702	0	48	56	978	0	35	9	1260	0	27	17
384	1	29	31	516	1	6	37	708	0	48	33	984	0	34	56	1266	0	27	9
386	1	29	3	519	1	6	14	714	0	48	9	990	0	34	43	1272	0	27	1
388	1	28	36	522	1	5	51	720	0	47	44	996	0	34	31	1278	0	26	54
390	1	28	9	525	1	5	29	726	0	47	21	1002	0	34	18	1284	0	26	46
392	1	27	41	528	1	5	6	732	0	46	57	1008	0	34	6	1290	0	26	39
394	1	27	18	531	1	4	45	738	0	46	35	1014	0	33	54	1296	0	26	31
396	1	26	48	534	1	4	22	744	0	46	12	1020	0	33	42	1302	0	26	24
398	1	26	24	537	1	4	1	750	0	45	50	1026	0	33	30	1308	0	26	17
400	1	25	56	540	1	3	39	756	0	45	28	1032	0	33	18	1314	0	26	10
402	1	25	31	543	1	3	19	762	0	45	7	1038	0	33	7	1320	0	26	2
405	1	24	53	546	1	2	58	768	0	44	46	1044	0	32	55	1326	0	25	55
408	1	24	15	549	1	2	37	774	0	44	25	1050	0	32	45	1332	0	25	48
411	1	23	38	552	1	2	16	780	0	44	4	1056	0	32	33	1338	0	25	41
414	1	23	2	555	1	1	56	786	0	43	44	1062	0	32	22	1344	0	25	34
417	1	22	26	558	1	1	36	792	0	43	24	1068	0	32	11	1350	0	25	28
420	1	21	51	561	1	1	17	798	0	43	5	1074	0	32	1	1356	0	25	21
423	1	21	16	564	1	0	57	804	0	42	45	1080	0	31	49	1362	0	25	14
426	1	20	42	567	1	0	38	810	0	42	26	1086	0	31	39	1368	0	25	7
429	1	20	8	570	1	0	19	816	0	42	7	1092	0	31	29	1374	0	25	1
432	1	19	35	573	1	0	0	822	0	41	49	1098	0	31	19	1380	0	24	54
435	1	19	2	576	0	59	41	828	0	41	31	1104	0	31	8	1386	0	24	48
438	1	18	29	579	0	59	22	834	0	41	13	1116	0	30	48	1398	0	24	35
441	1	17	57	582	0	59	4	840	0	40	55	1122	0	30	41	1404	0	24	28
444	1	17	26	585	0	58	46	846	0	40	38	1128	0	30	28	1410	0	24	22
447	1	16	54	588	0	58	27	852	0	40	21	1134	0	30	19	1416	0	24	16
450	1	16	24	591	0	58	10	858	0	40	4	1140	0	30	9	1422	0	24	10
453	1	15	53	594	0	57	52	864	0	39	47	1146	0	30	0	1428	0	24	4
456	1	15	23	597	0	57	35	870	0	39	31	1152	0	29	51	1434	0	23	58
459	1	14	54	600	0	57	17	876	0	39	14	1158	0	29	41	1440	0	23	52
462	1	14	24	606	0	56	44	882	0	38	58	1164	0	29	32	1446	0	23	46
465	1	13	56	612	0	56	10	888	0	38	43	1170	0	29	33	1452	0	23	40
468	1	13	27	618	0	55	38	894	0	38	27	1176	0	29	14	1458	0	23	35
471	1	12	59	624	0	55	5	900	0	38	12	1182	0	29	5	1464	0	23	28
474	1	12	32	630	0	54	34	906	0	37	56	1188	0	28	56	1470	0	23	23
477	1	12	24	636	0	54	3	912	0	37	41	1194	0	28	47	1476	0	23	17
480	1	11	37	642	0	53	33	918	0	37	27	1200	0	28	39	1482	0	23	12
483	1	11	10	648	0	53	3	924	0	37	12	1206	0	28	31	1488	0	23	6
486	1	10	44	654	0	52	34	930	0	36	58	1212	0	28	22	1494	0	23	0
489	1	10	18	660	0	52	5	936	0	36	43	1218	0	28	13	1500	0	22	55
492	1	9	52																

TABLE XXV.—USEFUL CONSTANTS.

Ratio of circumference to diameter of a circle .. .. $= \pi = 3 \cdot 141592653590$.

Log $\pi = 0 \cdot 497149872694$

$\pi^2 = 9 \cdot 869604401089$ .. .. $\sqrt{\pi} = 1 \cdot 772453850906$

Arc of same length as radius .. .. $= 180^\circ \div \pi = 10800' \div \pi = 648000'' \div \pi$.

$180^\circ \div \pi = 57^\circ \cdot 2957795130$ .. .. log $= 1 \cdot 758122632409$

$10800' \div \pi = 3437' \cdot 7467707849$ .. .. log $= 3 \cdot 536273882793$

$648000'' \div \pi = 206264'' \cdot 8062470964$ .. .. log $= 5 \cdot 314425133176$

Tropical year $=$ 365d. 5h. 48m. 47s.·588 $=$ 365d.·242217456 .. .. log $= 2 \cdot 5625810$.

Sidereal year $=$ 365d. 6h. 9m. 10s.·742 $=$ 365d.·256374332 .. .. log $= 2 \cdot 5625978$.

24h. sol. t. $=$ 24h. 3m. 56s.·555335 sid. t. $=$ 24h. $\times\ 1 \cdot 00273791$ .. log $1 \cdot 002 = 0 \cdot 0011874$.

24h. sid. t. $=$ 24h. $-$ (3m. 55s.·90944) sol. t. $=$ 24h. $\times\ 0 \cdot 9972696$ log $0 \cdot 997 = 9 \cdot 9988126$.

British Imperial gallon $= 277 \cdot 274$ cubic inches .. .. log $= 2 \cdot 4429091$.

10 lbs. of distilled water at 62° F. $=$ 1 gallon.

Length of sec. pend. in inches, at London, 39·13929; Paris, 39·1285; New York, 39·1285.

French mètre $= 3 \cdot 2808992$ English feet $= 39 \cdot 3707904$ inches.

1 cubic inch of water (bar. 30 inches, Fahr. therm. 62°) $= 252 \cdot 458$ Troy grains.

TABLE XXVI.—APPROXIMATE TIME OCCUPIED IN COURSE OF POST FROM LONDON TO CERTAIN PLACES ABROAD.

Name of Place.	Days.	Hours.	Name of Place.	Days.	Hours.	Name of Place.	Days.	Hours.	Name of Place.	Days.	Hours.
Accra	28	..	Cape Palmas	20	..	Manila ..	32	..	St. Vincent		
Adelaide ..	34	..	Cape Town	19	..	Marseilles..	1	2	(Cape de		
Aden	11	..	Carthagena	21	..	Mauritius ..	22	..	Verd) ..	10	..
Alexandria..	5	11	Chicago ..	9	12	Melbourne	35	..	St. Vincent		
Algiers ..	2	18	Colombo ..	17	..	Mexico ..	14	..	(West Indies)	12	20
Ambriz ..	47	..	Colon ..	19	1	Mombasa ..	22	..	Salonica ..	4	..
Antigua ..	14	17	Congo ..	26	..	Monrovia ..	20	..	Samoa ..	47	..
Arica—			Constanti-			Monte Video	23	..	San Francisco	12	..
(*viâ* Panama)	35	..	nople ..	4	..	Montreal ..	9	..	Santanda ..	2	12
(,, Magellan)	48	..	Coquimbo ..	42	..	Montserrat ..	14	7	Santos ..	23	..
Ascension ..	28	..	Cyprus ..	11	..	Moscow ..	3	16	Savanilla ..	22	..
Athens ..	5	6	Delagoa Bay	26	..	Mozambique	49	..	Seychelles..	17	..
Auckland(*viâ*			Demerara ..	13	20	Muscat ..	24	..	Shanghai—		
S. Francisco)	33	..	Dominica ..	13	16	Naples ..	2	3	(*viâ* Van-		
Baden-Baden	..	22	Falkland Is-			Natal.. ..	25	..	couver) ..	36	..
Baghdad ..	21	..	lands ..	29	..	Newfound-			(*viâ* Suez)		
Bahamas ..	14	..	Fiji	41	..	land ..	9	..	Sierra Leone	14	..
Bahia	17	..	Genoa.. ..	1	7	New York	8	12	Singapore ..	26	..
Balearic Is-			Gibraltar ..	4	6	Nova Scotia			Smyrna ..	6	..
lands ..	3	..	Gothenburg	1	22	(Halifax)	9	..	Suez	7	..
Barbadoes ..	11	23	Grand Bassa	19	..	Odessa ..	3	12	Sydney ..	38	..
Barcelona ..	1	16	Grenada ..	13	8	Old Calabar	15	..	Syracuse ..	3	7
Batavia ..	27	..	Grey Town	21	8	Oporto ..	3	2	Tamatave..	27	..
Bathurst ..	12	..	Guadeloupe	13	23	Ottawa ..	9	6	Teheran ..	22	..
Beirût	8	..	Guayaquil..	26	..	Palermo ..	2	22	Teneriffe ..	7	..
Belgrade ..	2	9	Havana	12	..	Panama ..	19	8	Tiflis	10	..
Belize	17	8	Hobart ..	37	..	Payta ..	26	..	Tobago ..	14	17
Benin	24	..	Hong Kong—			Penang ..	24	..	Transvaal		
Bergen.. ..	4	12	*viâ* Brindisi	33	..	Pernambuco	15	..	(*viâ* Cape)	23	..
Bermuda ..	15	..	,, Vancouver	40	..	Perth	34	..	Trieste ..	2	13
Bombay ..	16	12	Honolulu ..	20	..	Port-au-			Trinidad ..	13	21
Boston,			Iceland ..	10	..	Prince ..	15	..	Turin ..	1	3
U.S.A. ..	9	12	Jamaica ..	15	21	Port Said ..	6	..	Valparaiso—		
Brindisi ..	2	12	King George's			Quebec ..	9	..	(*viâ* Panama)	41	..
Brisbane ..	39	..	Sound ..	31	..	Rangoon ..	24	..	(,, Magellan)	39	..
Buda-Pesth..	2	..	Karachi ..	20	..	Reggio ..	3	..	Vancouver	15	..
Buenos Ayres	24	..	Lagos.. ..	29	..	RiodeJaneiro	19	..	Venice ..	2	..
Cadiz	3	12	Lamu ..	20	..	St. Helena	18	..	Vichy ..	..	21
Cairo	6	..	Lima	31	..	St. Kitts ..	15	10	Vigo	3	..
Calcutta ..	19	12	Limon ..	24	..	St. Louis,			Washington	9	..
Callao—			Lindi	29	..	U.S.A. ..	9	..	Wellington	36	..
(*viâ* Panama)	31	..	Lisbon ..	2	22	St. Lucia			Winnipeg..	13	..
(,, Magellan)	45	..	Madeira ..	4	..	(West Indies)	12	21	Yokohama—		
Cameroons ..	30	..	Madras ..	18	12	St.Petersburg	2	22	(*viâ* Van-		
Cape Coast			Malta.. ..	4	..	St. Paul de			couver) ..	32	..
Castle ..	26	..	Mandalay ..	28	..	Loanda ..	45	..	(*viâ* Suez)	43	..
						St. Thomas	16	3	Zanzibar ..	21	..

TABLE XXVII.—APPROXIMATE TIME OCCUPIED IN THE TRANSMISSION OF PARCELS FROM LONDON TO CERTAIN PLACES ABROAD.

	Days.	Hours.		Days.	Hours.
Accra	26	..	Lagos	29	..
Adelaide	44	..	Lahore	33	..
Aden	21	..	Lisbon, by direct steamer	4 to 8	..
Alexandria, *via* Gibraltar	18	..	Madras	31	..
,, *via* Brindisi	11	..	Malta, *via* Gibraltar	10	..
Algiers	4	..	Mandalay	41	..
Ajaccio	4	..	Marseilles	2	16
Antigua	15	8	Martinique	16	..
Ascension	24	..	Melbourne	46	..
Baghdad	45	..	Messina	5	15
Barbadoes	12	13	Muscat	45	..
Barranquilla	26	..	Naples	4	5
Batavia	44	..	Natal	27	..
Bathurst	14	..	Newfoundland	9	..
Beirût	21	..	Ottawa	12	..
Belize	36	..	Palermo	5	15
Bombay	27	..	Penang	34	..
Brindisi	5	..	Perth (Western Australia)	45	..
Buda-Pesth, *via* Cologne	5	12	Port Elizabeth	22	6
,, *via* Hamburg	6	12	Port Said, *via* Gibraltar	16	..
Cairo, *via* Gibraltar	17	..	,, *via* Brindisi	9	..
,, *via* Brindisi	13	..	Quebec	11	..
Calcutta	32	..	Rangoon	37	..
Cape Coast Castle	24	..	Réunion	23 or 33	..
Cape Town	20	..	St. Helena	16	..
Cayenne	23	..	St. Kitts	16	..
Colombo	28	..	St. Lucia (West Indies)	13	13
Constantinople, *via* Gibraltar	18	12	St. Thomas	17	..
,, *via* Marseilles	9	..	St. Vincent (West Indies)	13	16
Cyprus	24	..	Senegal	11	..
Delhi	32	..	Shanghai	48	..
Demerara	14	12	Sierra Leone	17	..
Dominica	14	8	Singapore	36	..
Drontheim	5	..	Smyrna, *via* Gibraltar	15	12
Genoa	2	13	,, *via* Marseilles	9	..
Gibraltar	7	..	Sydney	49	..
Gothenburg	2	11	Tobago	15	9
Grenada	14	..	Trieste, *via* Cologne	5	12
Guadeloupe	15	3	,, *via* Hamburg	6	12
Halifax (Nova Scotia)	10	..	Trinidad	14	13
Hong Kong	43	..	Venice	3	4
Jamaica	17	14	Victoria (Vancouver Island)	18	..
Kimberley	22	5	Winnipeg	16	..
King George's Sound	40	..	Zanzibar	33	..
Karachi	35	..	Zurich	1	10

N.B.—The times given above do not include the interval between the arrival of a Parcel at its place of destination and its delivery to the Addressee. Moreover, owing to Customs examination in the country of destination, a parcel not unfrequently occupies in transmission a longer time than is stated in the foregoing Table.

TABLES* FOR THE DETERMINATION OF HEIGHTS. *By* FRANCIS GALTON, F.R.S.

By the Temperature of Boiling Water.

Enter Table I., p. 313, with the boiling-point at each of the two stations, and extract the numbers that stand opposite to them in the column headed "Altitude, &c." The difference between these numbers gives the difference of height between the two stations, supposing the mean temperature of the intermediate air to be 32° Fahr. The correction for the temperature of the air, when it differs from this value, is given in Table II. We take the mean† of the thermometers (exposed in shade) at the upper and lower stations, and we enter Table II. with that mean value, and the number that stands opposite to it, in the column headed "Multiplier," must be multiplied with the results obtained from Table I. Thus:—

At station A the boiling-point	= 195°·1,	tabular number	= 9040
" B "	= 210°·3,	"	= 887
		Approximate difference of height	= 8153 feet.

* These extended Tables will give much facility to the traveller both in calculating altitudes, and in checking the index error of the aneroid, by means of the boiling-point thermometer. I have computed Table I. from Tables XXVI. and II., in the hypsometric series in Guyot's collection. It did not seem worth while to correct the figures thence obtained for the slight excess of temperature, viz.: 0°·015 Fahr. of the French boiling-point over that of the English. It is too small to be sensible in ordinary instruments, and it becomes totally unimportant in determining *differences* of level, or *changes* in the index error of an aneroid.—F. GALTON.

† This represents more nearly the average temperature of the intervening column of air than any other value that can easily be specified. But it is only an approximation of the truth.

To correct for temperature of intermediate air :—

At station A, temp. of air = 65° Fahr.

„ B, „ = 73° „

$$2\,)\,\underline{138}$$

69 = mean temperature of intermediate air.

In Table II. the multiplier corresponding to 69° is 1·082, and 1·082 × 8153 = 8821 (neglecting decimal fractions).

In those rare cases where greater altitudes are dealt with than are included within the limits of the table, the traveller should allow 570 feet for the difference between 185° and 184°; 572 feet for that between 184° and 183°; 574 feet for the next interval, and so on.

TABLE I.

Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.
185·0	14698	17·048	186·7	13733	17·690	188·4	12772	18·353
·1	14641	17·085	·8	13676	17·729	·5	12716	18·393
·2	14584	17·122	·9	13620	17·767	·6	12660	18·432
·3	14528	17·160	187·0	13563	17·806	·7	12603	18·472
·4	14471	17·197	·1	13506	17·844	·8	12547	18·512
·5	14414	17·235	·2	13450	17·883	·9	12490	18·552
·6	14357	17·272	·3	13394	17·922	189·0	12434	18·592
·7	14300	17·310	·4	13337	17·961	·1	12377	18·632
·8	14244	17·348	·5	13281	18·000	·2	12321	18·672
·9	14187	17·385	·6	13224	18·039	·3	12265	18·712
186·0	14130	17·423	·7	13167	18·078	·4	12209	18·753
·1	14073	17·461	·8	13111	18·117	·5	12153	18·793
·2	14017	17·499	·9	13054	18·156	·6	12096	18·833
·3	13960	17·537	188·0	12998	18·195	·7	12040	18·874
·4	13903	17·575	·1	12942	18·235	·8	11984	18·914
·5	13857	17·614	·2	12885	18·274	·9	11928	18·955
·6	13790	17·652	·3	12829	18·314	190·0	11872	18·996

TABLE I.—*continued.*

Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.
190·1	11816	19·036	194·5	9371	20·905	198·9	6962	22·924
·2	11760	19·077	·6	9315	20·949	199·0	6908	22·971
·3	11704	19·118	·7	9260	20·993	·1	6854	23·019
·4	11648	19·159	·8	9205	21·038	·2	6800	23·067
·5	11592	19·200	·9	9150	21·082	·3	6745	23·115
·6	11536	19·241	195·0	9095	21·126	·4	6691	23·163
·7	11480	19·283	·1	9040	21·171	·5	6637	23·211
·8	11424	19·324	·2	8985	21·216	·6	6583	23·259
·9	11368	19·365	·3	8930	21·260	·7	6529	23·308
191·0	11312	19·407	·4	8875	21·305	·8	6474	23·356
·1	11257	19·448	·5	8820	21·350	·9	6420	23·405
·2	11201	19·490	·6	8765	21·395	200·0	6366	23·453
·3	11146	19·532	·7	8710	21·440	·1	6312	23·502
·4	11090	19·573	·8	8655	21·485	·2	6258	23·550
·5	11034	19·615	·9	8600	21·530	·3	6203	23·599
·6	10978	19·657	196·0	8545	21·576	·4	6149	23·648
·7	10922	19·699	·1	8490	21·621	·5	6095	23·697
·8	10867	19·741	·2	8435	21·666	·6	6041	23·746
·9	10811	19·783	·3	8381	21·712	·7	5987	23·795
192·0	10755	19·825	·4	8326	21·751	·8	5933	23·845
·1	10699	19·868	·5	8271	21·803	·9	5879	23·894
·2	10644	19·910	·6	8216	21·849	201·0	5825	23·943
·3	10588	19·952	·7	8161	21·895	·1	5771	23·993
·4	10533	19·995	·8	8107	21·941	·2	5717	24·042
·5	10477	20·037	·9	8052	21·987	·3	5663	24·092
·6	10422	20·080	197·0	7997	22·033	·4	5609	24·142
·7	10366	20·123	·1	7942	22·079	·5	5556	24·191
·8	10310	20·166	·2	7888	22·125	·6	5502	24·241
·9	10255	20·208	·3	7833	22·172	·7	5448	24·291
193·0	10199	20·251	·4	7779	22·218	·8	5394	24·341
·1	10144	20·294	·5	7724	22·264	·9	5340	24·391
·2	10088	20·338	·6	7669	22·311	202·0	5286	24·442
·3	10033	20·381	·7	7615	22·358	·1	5232	24·492
·4	9978	20·424	·8	7560	22·404	·2	5178	24·542
·5	9923	20·467	·9	7506	22·451	·3	5124	24·593
·6	9867	20·511	198·0	7451	22·498	·4	5070	24·644
·7	9812	20·554	·1	7397	22·545	·5	5017	24·694
·8	9757	20·598	·2	7343	22·592	·6	4964	24·745
·9	9701	20·641	·3	7289	22·639	·7	4910	24·796
194·0	9646	20·685	·4	7234	22·686	·8	4856	24·847
·1	9591	20·729	·5	7180	22·734	·9	4802	24·898
·2	9536	20·773	·6	7125	22·781	203·0	4749	24·949
·3	9481	20·817	·7	7071	22·829	·1	4695	25·000
·4	9426	20·861	·8	7016	22·876	·2	4641	25·051

TABLE I.—*continued.*

Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.
203·3	4588	25·103	207·2	2516	27·179	211·1	469	29·390
·4	4535	25·154	·3	2464	27·231	·2	417	29·449
·5	4482	25·206	·4	2411	27·286	·3	365	29·508
·6	4428	25·257	·5	2358	27·341	·4	313	29·566
·7	4375	25·309	·6	2305	27·397	·5	261	29·625
·8	4322	25·361	·7	2252	27·452	·6	208	29·684
·9	4268	25·413	·8	2199	27·507	·7	156	29·744
204·0	4215	25·465	·9	2146	27·563	·8	104	29·803
·1	4161	25·517	208·0	2094	27·618	·9	52	29·862
·2	4107	25·569	·1	2041	27·674	212·0	0	29·922
·3	4053	25·621	·2	1989	27·730	·1	– 52	29·981
·4	4000	25·674	·3	1936	27·786	·2	– 104	30·041
·5	3947	25·726	·4	1884	27·842	·3	– 155	30·101
·6	3894	25·779	·5	1831	27·898	·4	– 207	30·161
·7	3841	25·831	·6	1778	27·954	·5	– 259	30·221
·8	3788	25·884	·7	1726	28·011	·6	– 311	30·281
·9	3735	25·937	·8	1673	28·067	·7	– 363	30·341
205·0	3682	25·990	·9	1621	28·123	·8	– 414	30·401
·1	3625	26·043	209·0	1568	28·180	·9	– 466	30·461
·2	3574	26·096	·1	1516	28·237	213·0	– 518	30·522
·3	3521	26·149	·2	1463	28·293	·1	– 570	30·583
·4	3468	26·202	·3	1411	28·350	·2	– 621	30·644
·5	3416	26·255	·4	1358	28·407	·3	– 673	30·705
·6	3363	26·309	·5	1306	28·464	·4	– 724	30·766
·7	3310	26·362	·6	1254	28·521	·5	– 776	30·827
·8	3256	26·416	·7	1201	28·579	·6	– 828	30·888
·9	3203	26·470	·8	1149	28·636	·7	– 880	30·949
206·0	3151	26·523	·9	1096	28·693	·8	– 932	31·010
·1	3098	26·577	210·0	1044	28·751	·9	– 983	31·071
·2	3045	26·631	·1	992	28·809	214·0	–1035	31·132
·3	2992	26·685	·2	939	28·866	·1	–1086	31·194
·4	2939	26·740	·3	887	28·924	·2	–1138	31·256
·5	2886	26·794	·4	835	28·982	·3	–1189	31·318
·6	2833	26·848	·5	783	29·040	·4	–1241	31·380
·7	2780	26·903	·6	730	29·098	·5	–1293	31·442
·8	2727	26·957	·7	678	29·156	·6	–1344	31·504
·9	2674	27·012	·8	626	29·215	·7	–1396	31·566
207·0	2622	27·066	·9	573	29·273	·8	–1447	31·628
·1	2569	27·121	211·0	521	29·331	·9	–1549	31·690

TABLE II.—CORRECTION FOR TEMPERATURE OF INTERMEDIATE AIR.

Mean temperature of intermediate air.	Multiplier.	Mean temperature of intermediate air.	Multiplier.	Mean temperature of intermediate air.	Multiplier.	Mean temperature of intermediate air.	Multiplier.
°		°		°		°	
20	0·9734	37	1·0111	54	1·0488	70	1·0844
21	0·9756	38	1·0133	55	1·0511	71	1·0866
22	0·9778	39	1·0155	56	1·0533	72	1·0888
23	0·9801	40	1·0177	57	1·0555	73	1·0911
24	0·9823	41	1·0199	58	1·0577	74	1·0933
25	0·9845	42	1·0222	59	1·0599	75	1·0955
26	0·9867	43	1·0244	60	1·0622	76	1·0977
27	0·9889	44	1·0266	61	1·0644	77	1·0999
28	0·9912	45	1·0288	62	1·0666	78	1·1022
29	0·9934	46	1·0311	63	1·0688	79	1·1044
30	0·9956	47	1·0333	64	1·0711	80	1·1066
31	0·9978	48	1·0355	65	1·0733	81	1·1088
32	1·0000	49	1·0377	66	1·0755	82	1·1111
33	1·0022	50	1·0399	67	1·0777	83	1·1133
34	1·0044	51	1·0422	68	1·0799	84	1·1156
35	1·0066	52	1·0444	69	1·0822	85	1·1178
36	1·0088	53	1·0466				

When the boiling point at the upper station alone is observed by the traveller, he sometimes has the opportunity of availing himself of some established observatory at no great distance, to serve as the lower station. A memoir by R. Scott, F.R.S., Secretary to the Meteorological Office, published with a map in Vol. XI. of the 'Journ. Roy. Meteor. Soc.,' shows the distribution of stations past and present, over the globe. But these are continually changing, so the intending traveller should seek the latest information at the Meteorological Office, 63, Victoria Street, S.W.

Usually, however, the traveller has no option but to take the mean height of the barometer, reduced to the sea-level, in the district in which he is, and for the same season of the year, and to use this in the place of observations at a lower station. He will find what he wants in the maps of mean barometric pressure, reduced to sea-level, that are given in most of the physical atlases. Berghaus' is the most recent of these; he gives one chart for summer and one for winter.* The charts published by the Meteorological Office refer to the ocean only, but they have the advantage of being quarterly, and are therefore preferable whenever the traveller's station is near the coast. It seems impossible to compress the information given by these charts into a form suitable to these pages,

* *See* Meteorological Maps, p. 356.

especially as the mean barometric height sometimes varies greatly in neighbouring places. The distance from Takutsk in Siberia to the Sea of Okhotsk is only 500 miles, yet in winter the calculated mean heights of the barometer at these two places, when reduced to sea-level, differ as much as 0·8 inch. From the latitude of Valdivia in S. America to Cape Horn, the distance is 900 miles, and the mean difference of barometric pressure is 0·5 inch. Vancouver is another district where the mean barometer differs much at moderate distances.

Whenever the observations at the upper and lower stations are not strictly simultaneous, or when the mean barometer is taken in place of the lower station, the correction for diurnal variation must not be omitted, especially in the tropics where, in other respects, the barometer is very steady. The mean amount of diurnal variation in different parts of the world is also given in Berghaus' maps. An error of one or two hundred feet might often be caused by the neglect to allow for it.

The traveller cannot be too strongly urged to have his boiling-point thermometer verified both before starting and after returning. Their index error is apt to vary, the thermometer reading lower than it should do after frequent use. This is especially the case for the first few years after they are made.

By Barometer or Aneroid.

The small but complete Tables (pp. 319, 320) will be especially useful to those who carry a mountain barometer and are anxious to make accurate determinations, but are not furnished with larger tables. These are calculated by Loomis, and are extracted from Guyot's collection.

Part I. gives the altitude, subject to correction, for the temperature of the air, and for the other influences which are the subjects of Parts II., III., IV., and V.

Method of Computation.—(1) Take from Part I. the two numbers corresponding to the two barometric heights; (2) from their difference subtract the correction found in Part II., with the difference between the thermometers that are attached to the barometers (*Mem.:* this correction is not wanted for aneroids, for their works are mechanically compensated for temperature); (3) for the temperature of the intermediate air between the two stations, multiply the nine-hundredth part of the value already obtained by the difference between the sum of the temperatures at the two stations and 64°. This correction is additive when the sum of the temperatures exceeds 64°, otherwise it is subtractive; or, what comes

to the same thing, use the multiplier already given in Table II., p. 316. (4) For further precision take corrections from Parts III. and IV., also from Part V., when the lower station is so high as to bring the case within the range of that table:—

(*Example* 1.)

	Upper Station.	Lower Station by Sea.
	°	°
Thermometer in open air	70·3	77·5
Thermometer in barometer	70·3	77·5
	Inches.	Inches.
Barometer	23·66	30·046
Latitude 21°.		
Part I. gives for 30·046 inches		27649·7
Part I. gives for 23·66 inches		21406·9
Difference		6242·8
Part II. gives for 77°·5 − 70°·3 (= 7°·2)		−16·9
Approximate altitude		6225·9
$\frac{6225 \cdot 9}{900} \times (77^{\circ} \cdot 5 + 70^{\circ} \cdot 3 - 64^{\circ}) = 6 \cdot 918 \times 83 \cdot 8$	=	+579·7*
Nearly correct altitude		6805·6
Part III. gives for above altitude and latitude 21°		+13·3
Part IV. gives for above altitude		+19·3
Part V. is not used in this case		0·0
Correct height above sea		6838·2 feet.

(*Example* 2.)
The Lower Station is in Lat. 30°, 4890 ft. above sea-level.

	Upper Station.	Lower Station.
	°	°
Thermometer in open air	32	89
Thermometer in barometer	35	89
	Inches.	Inches.
Barometer	15·76	25·07
Part I. gives for 25·07 inches		22919·3
Part I. gives for 15·76 inches		10791·3
Difference		12128
Part II. gives for 89° − 35°		−126
Approximate altitude		12001
$\frac{12001 \cdot 6}{900} \times (89^{\circ} + 32^{\circ} - 64^{\circ}) = 13 \cdot 3 \times 57$	=	+758
Nearly correct altitude		12759
Height of Lower Station		4890
		17649
From Part III.		22
From Part IV.		56
From Part V.		7
Altitude above the sea-level		17734

For high elevations it is needless to pay attention to decimals.

* If Table II., p. 320, had been used, we should have written—

$$\frac{77^{\circ} \cdot 5 + 70^{\circ} \cdot 3}{2} = 74^{\circ} \text{ nearly.}$$

The corresponding multiplier is 1·0933

$$1 \cdot 0933 \times 6225 \cdot 9 = 6806 \cdot 8.$$

PART I.

Argument, the observed Height of the Barometer at either Station.

Inches.	Feet.	Diff.	Inches.	Feet.	Diff.	Inches.	Feet.	Diff.	Inches.	Feet.	Diff.
11·0	1396·9	236·4	16·0	11186·3	162·8	21·0	18291·0	124·1	26·0	23871·0	100·3
11·1	1633·3	234·3	16·1	11349·1	161·8	21·1	18415·1	123·6	26·1	23971·3	99·9
11·2	1867·6	232·3	16·2	11510·9	160·8	21·2	18538·7	122·9	26·2	24071·2	99·5
11·3	2099·9	230·2	16·3	11671·7	159·8	21·3	18661·6	122·4	26·3	24170·7	99·1
11·4	2330·1	228·2	16·4	11831·5	158·8	21·4	18784·0	121·8	26·4	24269·8	98·8
11·5	2558·3	226·2	16·5	11990·3	157·9	21·5	18905·8	121·2	26·5	24368·6	98·4
11·6	2784·5	224·2	16·6	12148·2	156·9	21·6	19027·0	120·7	26·6	24467·0	98·1
11·7	3008·7	222·4	16·7	12305·1	155·9	21·7	19147·7	120·1	26·7	24565·1	97·6
11·8	3231·1	220·5	16·8	12461·0	155·1	21·8	19267·8	119·6	26·8	24662·7	97·3
11·9	3451·6	218·6	16·9	12616·1	154·1	21·9	19387·4	119·0	26·9	24760·0	97·0
12·0	3670·2	216·8	17·0	12770·2	153·3	22·0	19506·4	118·5	27·0	24857·0	96·6
12·1	3887·0	215·0	17·1	12923·5	152·3	22·1	19624·9	118·0	27·1	24953·6	96·2
12·2	4102·0	213·3	17·2	13075·8	151·5	22·2	19742·9	117·4	27·2	25049·8	95·9
12·3	4315·3	211·6	17·3	13227·3	150·6	22·3	19860·3	116·9	27·3	25145·7	95·5
12·4	4526·9	209·8	17·4	13377·9	149·7	22·4	19977·2	116·4	27·4	25241·2	95·2
12·5	4736·7	208·2	17·5	13527·6	148·9	22·5	20093·6	115·8	27·5	25336·4	94·8
12·6	4944·9	206·5	17·6	13676·5	148·0	22·6	20209·4	115·4	27·6	25431·2	94·5
12·7	5151·4	205·0	17·7	13824·5	147·2	22·7	20324·8	114·8	27·7	25525·7	94·2
12·8	5356·4	203·3	17·8	13971·7	146·3	22·8	20439·6	114·4	27·8	25619·9	93·8
12·9	5559·7	201·7	17·9	14118·0	145·6	22·9	20554·0	113·8	27·9	25713·7	93·4
13·0	5761·4	200·2	18·0	14263·6	144·7	23·0	20667·8	113·3	28·0	25807·1	93·2
13·1	5961·6	198·7	18·1	14408·3	144·0	23·1	20781·1	112·9	28·1	25900·3	92·8
13·2	6160·3	197·2	18·2	14552·3	143·1	23·2	20894·0	112·4	28·2	25993·1	92·5
13·3	6357·5	195·7	18·3	14695·4	142·4	23·3	21006·4	111·9	28·3	26085·6	92·1
13·4	6553·2	194·3	18·4	14837·8	141·6	23·4	21118·3	111·4	28·4	26177·7	91·9
13·5	6747·5	192·8	18·5	14979·4	140·9	23·5	21229·7	110·9	28·5	26269·6	91·5
13·6	6940·3	191·4	18·6	15120·3	140·0	23·6	21340·6	110·5	28·6	26361·1	91·2
13·7	7131·7	190·0	18·7	15260·3	139·4	23·7	21451·1	110·0	28·7	26452·3	90·9
13·8	7321·7	188·6	18·8	15399·7	138·6	23·8	21561·1	109·5	28·8	26543·2	90·5
13·9	7510·3	187·3	18·9	15538·3	137·9	23·9	21670·6	109·1	28·9	26633·7	90·3
14·0	7697·6	186·0	19·0	15676·2	137·1	24·0	21779·7	108·7	29·0	26724·0	89·9
14·1	7883·6	184·6	19·1	15813·3	136·5	24·1	21888·4	108·2	29·1	26813·9	89·6
14·2	8068·2	183·3	19·2	15949·8	135·7	24·2	21996·6	107·7	29·2	26903·5	89·3
14·3	8251·5	182·1	19·3	16085·5	135·0	24·3	22104·3	107·3	29·3	26992·8	89·1
14·4	8433·6	180·8	19·4	16220·5	134·3	24·4	22211·6	106·8	29·4	27081·9	88·7
14·5	8614·4	179·6	19·5	16354·8	133·7	24·5	22318·4	106·4	29·5	27170·6	88·4
14·6	8794·0	178·3	19·6	16488·5	132·9	24·6	22424·8	106·0	29·6	27259·0	88·1
14·7	8972·3	177·2	19·7	16621·4	132·3	24·7	22530·8	105·6	29·7	27347·1	87·8
14·8	9149·5	176·0	19·8	16753·7	131·6	24·8	22636·4	105·1	29·8	27434·9	87·6
14·9	9325·5	174·8	19·9	16885·3	131·0	24·9	22741·5	104·8	29·9	27522·5	87·2
15·0	9500·3	173·5	20·0	17016·3	130·3	25·0	22846·3	104·3	30·0	27609·7	86·9
15·1	9673·8	172·4	20·1	17146·6	129·7	25·1	22950·6	103·8	30·1	27696·6	86·7
15·2	9846·2	171·3	20·2	17276·3	129·0	25·2	23054·4	103·5	30·2	27783·3	86·4
15·3	10017·5	170·2	20·3	17405·3	128·4	25·3	23157·9	103·1	30·3	27869·7	86·0
15·4	10187·7	169·1	20·4	17533·7	127·7	25·4	23261·0	102·6	30·4	27955·7	85·8
15·5	10356·8	168·0	20·5	17661·4	127·2	25·5	23363·6	102·3	30·5	28041·5	85·6
15·6	10524·8	167·0	20·6	17788·6	126·5	25·6	23465·9	101·8	30·6	28127·1	85·2
15·7	10691·8	165·9	20·7	17915·1	125·9	25·7	23567·7	101·5	30·7	28212·3	85·0
15·8	10857·7	164·8	20·8	18041·0	125·3	25·8	23669·2	101·1	30·8	28297·3	84·7
15·9	11022·5	163·8	20·9	18166·3	124·7	25·9	23770·3	100·7	30·9	28382·0	84·4
16·0	11186·3		21·0	18291·0		26·0	23871·0		31·0	28466·4	

PART II.

CORRECTION DUE TO T—T′, OR THE DIFFERENCE OF THE TEMPERATURES OF THE BAROMETERS THEMSELVES (NOT FOR THAT OF THE INTERMEDIATE AIR) AT THE TWO STATIONS.

This Correction is Negative when the Temperature at the upper station is lowest, and vice versâ.

T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.
Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.
°		°		°		°		°		°	
1	2·3	14	32·8	27	63·2	40	93·6	53	124·1	66	154·5
2	4·7	15	35·1	28	65·5	41	96·0	54	126·4	67	156·8
3	7·0	16	37·5	29	67·9	42	98·3	55	128·7	68	159·2
4	9·4	17	39·8	30	70·2	43	100·7	56	131·1	69	161·5
5	11·7	18	42·1	31	72·6	44	103·0	57	133·4	70	163·9
6	14·0	19	44·5	32	74·9	45	105·3	58	135·8	71	166·2
7	16·4	20	46·8	33	77·3	46	107·7	59	138·1	72	168·6
8	18·7	21	49·2	34	79·6	47	110·0	60	140·4	73	170·9
9	21·1	22	51·5	35	81·9	48	112·4	61	142·8	74	173·3
10	23·4	23	53·8	36	84·3	49	114·7	62	145·1	75	175·6
11	25·8	24	56·2	37	86·6	50	117·0	63	147·5	76	177·9
12	28·1	25	58·5	38	89·0	51	119·4	64	149·8	77	180·3
13	30·4	26	60·9	39	91·3	52	121·7	65	152·2	78	182·6

PART III.

CORRECTION DUE TO THE CHANGE OF GRAVITY FROM THE LATITUDE OF 45° TO THE LATITUDE OF THE PLACE OF OBSERVATION.

Positive from Lat. 0° to 45°; Negative from Lat. 45° to 90°.

PART IV.

CORRECTION FOR DECREASE OF GRAVITY ON A VERTICAL.

Always Positive.

PART V.

CORRECTION DUE TO THE HEIGHT OF THE LOWER STATION.

Always Positive.

App. Alt.	Latitude. 0° / 90°	10° / 80°	20° / 70°	30° / 60°	40° / 50°	45°	Part IV.	Height of Barometer at Lower Station. 16 in.	18 in.	20 in.	22 in.	24 in.	26 in.	28 in.	App. Alt.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1000	2·6	2·5	2·0	1·3	0·5	0	2·5	1·6	1·3	1·0	0·8	0·6	0·4	0·2	1000
2000	5·3	5·0	4·1	2·6	0·9	0	5·2	3·1	2·5	2·0	1·5	1·1	0·7	0·3	2000
3000	7·9	7·5	6·1	4·0	1·4	0	7·9	4·7	3·8	3·0	2·3	1·7	1·1	0·5	3000
4000	10·6	10·0	8·1	5·3	1·8	0	10·8	6·3	5·1	4·0	3·1	2·2	1·4	0·7	4000
5000	13·2	12·4	10·1	6·6	2·3	0	13·7	7·8	6·4	5·0	3·8	2·8	1·8	0·8	5000
6000	15·9	14·9	12·2	7·9	2·8	0	16·7	9·4	7·6	6·0	4·6	3·3	2·1	1·0	6000
7000	18·5	17·4	14·2	9·3	3·2	0	19·9	11·0	8·9	7·1	5·4	3·9	2·5	1·2	7000
8000	21·2	19·9	16·2	10·6	3·7	0	23·1	12·5	10·2	8·1	6·2	4·4	2·8	1·3	8000
9000	23·8	22·4	18·3	11·9	4·1	0	26·4	14·1	11·4	9·1	6·9	5·0	3·2	1·5	9000
10000	26·5	24·9	20·3	13·2	4·6	0	29·8	15·7	12·7	10·1	7·7	5·5	3·5	1·7	10000
11000	29·1	27·4	22·3	14·6	5·1	0	33·3	17·2	14·0	11·1	8·5	6·1	3·9	1·8	11000
12000	31·8	29·9	24·4	15·9	5·5	0	36·9	18·8	15·3	12·1	9·2	6·6	4·2	2·0	12000
13000	34·4	32·4	26·4	17·2	6·0	0	40·6	20·4	16·5	13·1	10·0	7·2	4·6	2·2	13000
14000	37·1	34·9	28·4	18·5	6·4	0	44·4	21·9	17·8	14·1	10·8	7·7	4·9	2·3	14000
15000	39·7	37·3	30·4	19·9	6·9	0	48·3	23·5	19·1	15·1	11·5	8·3	5·3	2·5	15000
16000	42·4	39·8	32·5	21·2	7·4	0	52·3	25·1	20·3	16·1	12·3	8·8	5·6	2·7	16000
17000	45·0	42·3	34·5	22·5	7·8	0	56·4	26·6	21·6	17·1	13·1	9·4	6·0	2·8	17000
18000	47·7	44·8	36·5	23·8	8·3	0	60·5	28·2	22·9	18·1	13·8	9·9	6·3	3·0	18000
19000	50·3	47·3	38·6	25·2	8·7	0	64·8	29·8	24·1	19·2	14·6	10·5	6·7	3·2	19000
20000	53·0	49·8	40·6	26·5	9·2	0	69·2	31·3	25·4	20·2	15·4	11·0	7·0	3·3	20000
21000	55·6	52·3	42·6	27·8	9·7	0	73·6	32·9	26·7	21·2	16·1	11·6	7·4	3·5	21000
22000	58·3	54·8	44·7	29·1	10·1	0	78·2	34·5	28·0	22·2	16·9	12·1	7·7	3·7	22000
23000	60·9	57·3	46·7	30·5	10·6	0	82·9	36·0	29·2	23·2	17·7	12·7	8·1	3·8	23000
24000	63·6	59·8	48·7	31·8	11·0	0	87·6	37·6	30·5	24·2	18·5	13·2	8·4	4·0	24000
25000	66·2	62·2	50·7	33·1	11·5	0	92·5	39·1	31·8	25·2	19·2	13·8	8·8	4·1	25000

V.

PHOTOGRAPHY.

By W. F. Donkin, M.A., F.C.S., A.C., *late Lecturer in Chemistry at St. George's Hospital.*

Revised and brought up to date by J. Thomson, *Instructor in Photography R.G.S.*

The traveller who wishes to take photographs of the scenery he may pass through has first to decide on the size of plate he intends to employ, for on this will depend the size and weight of all the necessary apparatus. The smallest size that is worth taking is known as "quarter-plate," measuring $4\frac{1}{4} \times 3\frac{1}{4}$ inches; the largest size which admits of the apparatus being carried by one man is $7\frac{1}{2} \times 5$ inches. Intermediate sizes are 5×4, and $6\frac{1}{2} \times 4\frac{3}{4}$, or "half-plate."

On high mountain ascents, and in cases where scarcity of porters or some other reason may compel the traveller to carry his own apparatus, it may be advisable to have a "quarter-plate" camera, as, although the pictures obtained are trivial in appearance, excellent enlargements and lantern slides can be produced from them. In countries where, as in India, porterage is cheap and easily obtained, large sizes may be adopted, such as $8\frac{1}{2} \times 6\frac{1}{2}$ or "whole-plate"; but for general utility and convenience $7\frac{1}{2} \times 5$ is recommended, and in the following remarks it will be assumed that this is the size adopted.*

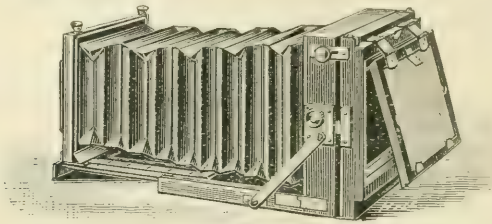
The next point to decide is as to the selection of the sensitized medium for receiving the image—glass plates, celluloid, or other films.

The weight of the entire apparatus necessary for taking twelve pictures, namely, camera, slides, 12 glass plates, lenses, leather case, and tripod stand, will be from 20 to 25 lbs. The weight of glass plates $7\frac{1}{2} \times 5$ inches averages 3 lbs. per dozen, and, as the traveller should take with him from half a gross upwards, it is evident that the chief weight of the necessary photographic impedimenta is solid glass. This weight may be much

* A "quarter-plate" camera ought to be taken to supplement the work of the larger instrument, and to be used either as a hand camera, or on a tripod stand.

diminished by using flexible celluloid films as the base for the sensitive gelatine film. Without doubt, glass plates yield the best results; but celluloid films in the smaller sizes, up to $7\frac{1}{2} \times 5$, approach very nearly to glass in many respects, and have the advantage of being one-twelfth the weight and not liable to breakage. They are exposed in the same slides, and require the same treatment as glass plates.

As, however, the production of good film negatives requires considerable skill and nicety of manipulation, it will be well for the traveller who has not been able to attain expertness therein, to provide himself with glass plates and flat celluloid films. The following list comprises all the apparatus necessary for taking photographs on dry gelatine-coated glass plates or celluloid films.



Bellows Camera.

1. *A camera.*—This should be of the bellows-bodied form, of best mahogany, thoroughly well seasoned, and it is very convenient for it to be fitted with what is known as a reversive back. It should have a moveable front, capable of shifting both vertically and horizontally; and a swing back; that is to say, the frame carrying the focussing glass and sensitive plates must be capable of turning on a vertical axis through several degrees in each direction away from the normal. There are now many good camera-makers in London; among the best may be named Mr. Meagher, of 21, Southampton Row, Ross, of Bond Street, and Mr. Hare, of 26, Calthorpe Street, Gray's Inn Road.

The essential points required in a camera for travelling are lightness combined with strength, rigidity when extended for use, and absence of loose parts and screws. When the form of camera allows it, the tripod head is better dispensed with, and a turn-table let into the base board. If this be not the case, have all screws in duplicate. A convenient screw

is made for fixing the camera to the stand. The thread of the screw is turned off close to the shoulder, so that the screw revolves in the aperture in the head of the stand, and need never be withdrawn. A second focussing screen should also be taken, or some fine emery with which to grind down a glass plate in case of breakage.

Hand cameras.—It is necessary to supplement the note on hand cameras, as they are now extensively used, and excellent work done with them. Hand cameras are designed to carry a dozen or more plates or films in flat sheets or in spools, so arranged inside the camera as to be changed after each exposure by simply turning a milled head, or moving a lever. The Key camera made by the Platinotype Company is certainly one of the best; it is fitted with metal dark slides for carrying plates or films, and is well spoken of by Mr. Conway. It may be had either to carry plates or flat films. These metal slides are light, not easily damaged, and offer greater security against damp than an ordinary hand-camera where slides are not used. Where the film takes the form of a roll, the Luzo hand-camera is excellent, but rolled films are not recommended for travellers' use in hot and humid climates, for reasons which I will note later on. Mr. Conway's experience of the Key camera for work in high mountain ranges proves its capabilities for the general work of exploration. He says: "A traveller who carries glass plates and flat films will probably bring home a larger percentage of good negatives from a long mountain journey than one who relies upon spools of films." There can be no question about the force and accuracy of this statement. My own experience goes to prove that a camera arranged for glass plates and flat films is best. There is a certain facility in using rolled films, but the risk of failure is great. The Key camera should be fitted with a rising front for taking elevated objects in correct drawing when the instrument is level. Mr. Conway advises that " the angles of the double backs of this camera should be made stronger than they usually are. The shutter spring should be carefully tested for quality before starting, and a duplicate spring taken, which the traveller should learn to adjust."

In addition a light tripod stand should be taken for supporting the camera when longer exposures are required than can be given in the hand. A very satisfactory compromise has been adopted by Capt. Abney between using the camera in the hand and on a tripod. He rests the camera on top of a walking stick when making hand exposures, with the

result that he overcomes all tremor caused by pulsation, and so secures photographs full of sharp detail. There are a number of excellent hand-cameras made, those by Ross, Rouch, and Watson may be mentioned.

2. *Slides for holding the sensitive plates.*—These are frames which slide into the back of the camera in place of the focussing glass, which is removed. They each hold two sensitive plates, back to back, with an opaque partition between them, so that a dozen plates will require six slides or "double backs."

In order to secure the camera against the admission of light when the plate is being exposed, cover the camera entirely with the focussing cloth leaving the lens free, and pull out the shutters of the slides under the cloth.

3. *A focussing cloth.*—This is used for keeping out the light while focussing, being thrown over the camera and the head of the operator. It is generally made of black velvet, but waterproof sheeting is much better. It should have rings sewn on to one edge, or some arrangement by which it may be attached to the camera so as not to be blown away.

4. *Camera-stand.*—There are many varieties of tripod stands, with legs either folding or sliding into a small compass. For mountainous country it is of great advantage to have a stand with sliding legs, as they can be readily altered in length so as to stand firmly on slopes or rocky ground. Kennett's is a good form of sliding stand, and is made in two or three different sizes. The smallest size, weighing about 3 lbs., and measuring 33 in. long when closed, and standing about 4 ft. 6 in. high, is steady enough to support a $7\frac{1}{2} \times 5$ camera without perceptible vibration in a moderate wind. That of Hunter & Sands is another very good pattern.

5. *A small circular cup level*, let into the wood of the camera, for levelling the camera on the tripod.

Lenses.—There are many lenses in the market, and as it is impossible to do good work with an inferior lens, it is necessary to exercise great care in selecting this part of a photographic outfit. Lenses known as rectilinear or symmetrical are the most useful to a scientific explorer, and are equally well fitted for producing pictorial effect in his work.

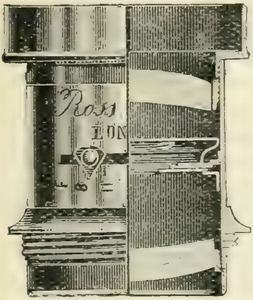
Ordinary portrait lenses are designed specially for rapid work, and this is attained at the cost of qualities in a lens most useful to an explorer. The so-called portrait combination should therefore be avoided, and there is all the more reason for this as rapid rectilinear and symmetrical lenses are well adapted for out-door portraiture.

Rectilinear and symmetrical lenses give true images of objects to be

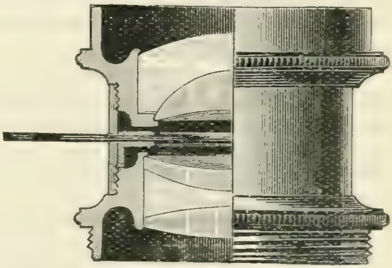
photographed free from distortion, so that straight lines are reproduced as straight lines. In this way they are invaluable where accurate measurements have to be taken from photographs produced by them.

Ross and Dallmeyer's ordinary symmetrical and rectilinear lenses are excellent for all sorts of landscape work and for photographing buildings, exterior and interior. In using a camera $7\frac{1}{2}$ in. $\times$ 5 in. the following lenses are recommended:—

a. Ross's portable symmetrical, 5 in. focus. (This embraces an angle of about 55° on the long diameter of the plate, and is useful for confined situations and interiors, but should seldom be used for an open land-



Ross Rapid Symmetrical.



Zeiss Lens.

scape.) *b.* Dallmeyer's single meniscus lens, 7 in. focus. (This includes an angle of about 45° on the $7\frac{1}{2}$ in. plate, and will be found the most universally useful lens for ordinary landscapes, giving a brilliant image with great depth of focus.) *c.* Dallmeyer's rapid rectilinear, of about 11 in. focus, including about 37°. *d.* Zeiss's anastigmat, made by Ross, consists of a double front lens and a triple back lens. It is intended for portraits, groups, copying, and general outdoor work. The combinations being brought closely together, gives them great illuminating power. They have an angular aperture of from 858 to 908, and can therefore be used as wide-angle lenses when desired. In consequence of the peculiar system of correction for oblique pencils adopted in these lenses they behave somewhat differently from the usual types with regard to the mode of compensating the effect of the resulting aberrations between centre and margin of the field. This is, of course, only possible in the

case of perfectly plane objects. In all other cases—landscape, instantaneous work, or interiors—the centre should be focussed, and rather for objects at a distance than for near objects. Considerable economy may be effected by purchasing lenses second-hand from respectable dealers, such as Messrs. Watson & Son, 313, High Holborn; Mr. Morley, 70, Upper Street, Islington, or Messrs. Hunter & Sands, of 20, Cranbourne Street, all of whom can be recommended with confidence.

Focus.—In place of giving a strictly scientific definition of the term focus or "focul length" applied to a lens, it will be sufficient for the scope of this paper to say that focul length means the distance between the diaphragm of a rectilinear or symmetrical lens, and the ground-glass screen of a camera. That is when the image of an object, say one hundred yards in front of the lens, is seen most distinctly on the focussing screen of the camera.

Exposure tables.—Exposure tables are based on the focul length of a lens, in relation to the diameter of the diaphragm of a lens. Thus, if the focus is eight inches and diameter of diaphragm one inch, the relationship will be expressed by $\frac{f}{8}$ or by the uniform standard number 4, and so on, as in table.

U. S. Nos.	4	8	16	32	64	128	256
Ratio of Stops	$\frac{f}{8}$	$\frac{f}{11 \cdot 3}$	$\frac{f}{16}$	$\frac{f}{22 \cdot 6}$	$\frac{f}{32}$	$\frac{f}{45 \cdot 2}$	$\frac{f}{64}$

Such tables are useful guides to the relative duration of exposure with diaphragms of different sizes applied to the same lens. They afford no clue, however, to time of exposure to be given with any particular lens or diaphragm. This can be best ascertained by experience, as duration of exposure of a plate or film in the camera depends on the sensitiveness of the plate, the time of day, the sun, the state of the atmosphere, the nearness or distance of the object to be photographed, etc. To take an extreme case of the difference of time required to impress the plate with the image of an exterior view and that of an interior, a landscape open and well lighted may be taken in the fraction of a second, while a dimly-lighted interior with the same lens would require an hour, both being taken with plates coated with the same emulsion.

Sensitive plates or films.—Gelatine plates are now made commercially by a large number of firms and of great excellence; they keep indefinitely before exposure, and for a long time afterwards and before development, and under some circumstances (as for instantaneous pictures, portraits, and dimly-lighted interiors) will give results which could hardly be obtained at all on collodion. Gelatine plates are made of various degrees of sensitiveness; the slowest plates are best for ordinary landscape work. They are generally supplied in parcels of a dozen each, packed face to face with strips of folded paper between opposite edges. The card boxes in which they are usually packed are an insufficient protection against injury and damp. In all cases it is advisable, and for sea voyages and damp climates essential, to have each package of a dozen plates soldered down in a tin case, and afterwards packed in a light wooden box with tow or cotton wool, and the box screwed (not nailed) down. In packing them up again after exposure or after development, a good plan (due to Captain Abney) is to provide oneself with a number of cardboard frames exactly the size of the plates, made of strips of card about ¼ in. wide, one of which is inserted between every two face to face. The packages thus made up should be soldered down again, and treated with at least as much care as the original plates. Should there be no available means of resoldering the boxes, it will be better to have tin boxes with the lid turned well down, the joinings to be closed by strong well-gummed paper. It will also be well to be provided with a supply of waterproof paper, or cloth, as an additional precaution in packing and in case of emergencies.

Sensitive films in rolls or spools are made by the Eastman and other companies, and may be used successfully in their proper roll-holders when they can be kept perfectly dry. Flat films made by Fitch, Edwards and others have many advantages for travellers. The celluloid of which they are made is very much lighter than glass, and in exposure and development may be treated in the same way as a glass plate.* When plates can be carried, the extra weight is compensated for by greater certainty of success, and general excellence in the photographs.

How to keep plates and films dry.—When the traveller has a long journey before him, and the prospect of storing his plates and films for months

* A new film has just been introduced by Thomas, of Pall Mall, and is said not to possess the defects of celluloid.

both before and after exposure, it is of the greatest importance that precautions should be taken against the inroads of damp. This applies with full force when the country to be explored has a hot, humid climate. Plates and films that have absorbed moisture, causing decomposition in the sensitive gelatine coating, are frequently brought back to this country to be developed, and are the most fruitful cause of failure. The remedy is simple, but can only be applied when packing and repacking the plates. Some guarantee should be sought from makers of plates and films that they are packed perfectly dry, and that the packing used is also dry. Assuming that work has to be done in a damp climate and that the plates have been exposed in the camera and require to be repacked, they should be dried in a box containing a small quantity of chloride of calcium. The box used for drying may be also designed to carry the camera and outfit. It should have a lid with a rim of rubber padding, so that by putting the lid on and a weight on it, the box would be fairly air-tight. Stack the exposed plates, or films, in the bottom of box, so separated as to permit the passage of air between. Place a cup or saucer on the bottom of box containing chloride of calcium. (The chloride should be first dried on a piece of iron over a fire.) Put on the lid and allow the plates to remain for an hour or more. Dry all the packing materials, remove the plates from the box and repack. The chloride will have absorbed the moisture in the plates, and rendered them quite dry and safe for preserving for an indefinite length of time.

Apparatus and chemicals for development.—The development of the plates or films after exposure in the camera requires practice and experience in order to secure the best results. Instructions for development are sent out with all commercial plates or papers, but many failures would certainly result from attempting to work by these without some preliminary practice at home. As plates, &c., will keep after exposure (if well protected from damp) for 18 months, or longer if properly packed, it is not, of course, necessary to develop them *en route*, although if the traveller possess sufficient skill, and if ample water-supply and other facilities can be secured, it will be advantageous for many reasons to do so. On a long journey, use of convenient resting-places may be made to develop from time to time a few plates selected from the whole, both as tests for exposure and as proof that all the apparatus is in order. The following list comprises all that is

absolutely required for developing 8 or 10 dozen gelatine plates:—Three papier-mâché dishes, two 3-ounce glass measures, three 6-ounce bottles, containing strong solutions of pyrogallic acid, potassium bromide, and ammonia respectively, 1 lb. hyposulphite of soda, and ¼ lb. alum, both in crystals, 4 or 5 feet of indiarubber tubing and a spring clip, to make a syphon for a water-supply from a jug or can, a basin or tub to serve as a sink, a folding rack for draining the plates.

There is a very convenient new developing agent in the market called Eikonogen, sold in tubes, and may be used as follows:—Break the tube over a sheet of paper, empty completely both halves by means of pressing the tube between the fingers, withdraw the small pieces of wadding falling therefrom and put the whole quantity of the powder in a bottle containing 100 cubic-centimetres (3½ ounces) distilled water. (Rain-water or soft pump-water may also be used.) After being shaken from 3 to 5 minutes, the powder will dissolve, and the developer is then ready for use. If the plates are over-exposed, increase the quantity of water from 150 to 200 cubic-centimetres, and, if necessary, add a few drops of a solution of bromide of potassium (1 : 10). The developer may be used several times.

The traveller is recommended for advanced study of photography, such works as that by Captain Abney or by W. K. Burton, which may be had from any photographic dealers.

The aim of the traveller-photographer should be the production of good *negatives*. It often requires years of study on the part of professional operators (with advantages impossible to the traveller) before thoroughly good negatives are habitually produced; and it must not be supposed that a person taking up photography for the first time, in a few hurried moments before departure on a journey, will attain other than very unsatisfactory results.

The operations necessary for taking a picture are briefly as follows:—Having selected the position from which the view is to be taken (for valuable hints as to the *artistic* production of pictures see Robinson's 'Pictorial Effect in Photography'), the tripod stand is first set up, and the head approximately levelled by means of the pocket level, altering the position or length of the legs as may be necessary. The camera is next screwed on to the stand, and the lens selected which on trial is found to include the required amount of subject. For groups or portraits a long focus lens with wide aperture, such as Dallmeyer's "Rapid rectilinear," 11 in. focus,

should be used. The next operation is to focus the picture accurately on the ground-glass screen of the camera. The focussing-cloth is thrown over the head and the camera, so as to exclude the light as much as possible, and while looking at the inverted image on the ground glass the milled head of the rack adjustment is turned till the image appears as sharp as possible. The camera is now turned about on its vertical axis till it exactly includes the view intended to be taken, and the screw is tightened. It may be necessary to raise or lower the front of the camera carrying the lens in order to include objects at a high or low elevation; if the vertical range of this sliding front is insufficient, the camera must be tilted; but, if this is done, care must be taken to set the focussing-screen vertical again by means of the swing back, and to re-adjust the focus. The full aperture of the lens should always be used for focussing, and if the image is not sharp all over the plate it will be necessary to insert a diaphragm in the lens, using the largest that will effect the required object. Having then put the cap on the lens, the hinged frame carrying the focussing-glass is turned over, and one of the slides carrying the sensitive plates is inserted in its place. The slides should be exposed as little as possible to the light, especially avoiding direct sunlight; however carefully constructed, it is difficult to make them absolutely light-tight. The shutter of the slide is then withdrawn, and the exposure made by removing the cap from the lens for the required time. The time of exposure must be estimated according to circumstances, and it requires considerable experience to judge of it accurately. A record should be kept in a note-book of every plate exposed, giving the number, date, time, exposure, subject, &c. If the plates cannot be developed the same evening, and the slides are wanted for fresh plates, they must be packed up again, and should be numbered. This is best done by marking the number on the back with a bit of dry soap, or on the film with a lead pencil. The image on the plate after exposure is latent and invisible, and has to be developed. This is effected by pouring on the plate, laid in one of the flat dishes, a dilute solution containing pyrogallic acid, ammonia, and potassium bromide. The excellence of the result largely depends on the due proportion between these constituents, and here more experience is perhaps necessary than in any other part of the process. The image having been fully developed, the plate is well washed, and then immersed in

a solution of alum, which hardens the film. After another thorough washing it is "fixed" by immersion in a solution of sodium hyposulphite, which dissolves out the unchanged bromide of silver, and being once more well washed it is finished, and must be set up in the rack to dry spontaneously. On no account must heat be applied, not even the warmth of sunlight, or the film will melt. When dry it must be varnished to protect the film. The printing operations are best deferred till the return home, as they would involve the carriage of a large amount of extra apparatus. It is generally best to get the printing done by a professional printer; but, if the traveller prefers to print from his own negatives, he will find full instructions in 'The Art and Practice of Silver Printing,' by Robinson and Captain Abney.

As regards the expense of a photographic outfit, such as that described above, the following may be taken as average prices for the largest size recommended, namely, for plates $7\frac{1}{2} \times 5$ inches:—

Camera 4 to 5 guineas.

Double slides, about 1 guinea each.

Lenses, as described above, No. 1, 3*l.* 10*s.*; No. 2, 3*l.* 15*s.*; No. 3, 7*l.* These may generally be obtained second-hand, in good condition, at a reduction of 25 or 30 per cent. on these prices.

The above may be arranged to pack into a solid leather case, conveniently in the form of a knapsack, measuring about 16 in. wide, 12 in. high, and 5 in. deep. This can easily be carried on the back of one man, and is of a more convenient shape than the cases generally sold for the purpose.

Tripod stand, 25*s.*

Lantern, from 2*d.* to 10*s.*

Gelatine plates, about 3*s.* per dozen.

Apparatus and chemicals for development, about 15*s.*

Total, exclusive of the plates, about 25*l.*

The plates and other apparatus, with the exception of the knapsack and its contents, and the tripod stand, are best packed for travelling in a strong basket, which is much better than a box, being more elastic and lighter. It will weigh, when packed with the apparatus and a gross of $7\frac{1}{2} \times 5$ plates, about 60 lbs.

Travellers interested in anthropology might read Mr. E. F. im Thurn's recent paper on the Anthropological Uses of the Camera, published in the 'Proceedings of the Anthropological Society.'

VI.

METEOROLOGY AND CLIMATE.

By H. F. Blanford, F.R.S.

Before starting on his journey, the traveller should set before himself what he contemplates as the precise aim and object of his meteorological observations, and arrange his outfit and plan of operations accordingly. This object may be, either (1) a simple record of the weather, (2) a knowledge of the local climate, or (3) the prosecution of certain special meteorological inquiries, for which the places he proposes to visit may afford peculiar advantages.

Since the climate of a country is the average of all its weather conditions at each season, the observations which are required for the first object need only to be made systematically and guarded with certain precautions in order to furnish a valuable contribution towards the second also; and it may therefore be assumed that, as a general rule, this too is desired. To accomplish the third object, some previous scientific knowledge and practice will generally be necessary, and this will best be gained by a preliminary training under competent guidance. Some suggestions on this head will be given in the sequel.

Assuming, then, that a knowledge of the climate is the object immediately in view, the following particulars will more especially claim the traveller's attention. 1st, the temperature of the air, including the mean temperature, its diurnal and annual range, and its variability from day to day. 2nd, the humidity of the air at different seasons, and its changes; 3rd, the rainfall, including under this head snow, hail, dew, and other forms of precipitation; 4th, the direction and force of the wind; 5th, the cloudiness or serenity of the sky, with observations of fog and dust-haze; 6th, the frequency of storms. The intensity of the sun's heat and the cooling of the earth at night are also very important elements of climate, but the

instruments for measuring them are fragile, and especially liable to destruction. And inasmuch as, in the absence of direct observation, the sun's intensity and the nocturnal cooling may be, to a certain extent, inferred from the temperature range and some other of the foregoing observations, their actual measurement can hardly be recommended except under special circumstances to be noticed presently. The variations of the pressure of the atmosphere are of less importance as an element of climate, but they hold a first place in connection with weather changes, and with the movements of the atmosphere; and, inasmuch as the barometer (or aneroid) affords the readiest means of determining the elevation of a place, it will form part of the outfit of most travellers, and will be here noticed among the more indispensable instruments.

Instruments and outfit.—For the purposes specified in the foregoing paragraph, the following instruments are requisite:—

1 self-registering maximum thermometer.
1 ,, ,, minimum ,,
1 dry and wet bulb hygrometer.
2 sling thermometers.
1 thermometer for earth temperatures.
1 rain-gauge.
1 aneroid.
1 pocket compass.

Also a portable stand and screen for the thermometers; half a yard of thin muslin and a skein or two of lamp wick cotton for renewing the covering of the wet bulb thermometer, a pocket note-book for noting down the readings of the instruments and other casual observations, and a ruled register for posting them as a permanent record.

The instruments above enumerated will suffice for ordinary purposes if the journey is not likely to be very prolonged, and the means of transport such as will not expose them to great risk. If otherwise, all but the rain-gauge should be provided in duplicate. An ordinary reading lens, of about 2 in. diameter and 4-in. focus, is sometimes useful for the accurate and rapid reading of the thermometers. And if the country is one where no good mercurial barometer is likely to be met with, and circumstances admit of one being set up at a fixed station, which can be referred to at intervals, or even the beginning and end of the journey, for the comparison

of the aneroid, it will be a most useful adjunct; but even the most portable forms of the mercurial barometer are so fragile, and their transport on land journeys is attended with so much risk, that, as a general rule, they can hardly be recommended for the purposes of travel.

Small self-registering thermometers for travellers are procurable from the best London makers, and are as trustworthy as the larger observatory instruments, while they are more portable. The best form of maximum thermometer is that which has the tube constricted just above the bulb, so that the column, in contracting after attaining the maximum temperature, breaks at this point. The more usual pattern (Phillip's) has an air-bubble about an inch below the top of the column. This is apt to shift in travelling, and sometimes to escape from the column, and the instrument then ceases to be self-registering. Six's thermometer, which combines the maximum and minimum in one bent tube, partly filled with mercury and partly with spirit, is also liable to be deranged in travelling, and is not more portable than the separate instruments of small size.

The minimum thermometer should be a spirit thermometer of the form known as Rutherford's, which has an index of black glass immersed in the spirit column. This is also very liable to derangement in travelling, and sometimes even when suspended for observation, owing to the separation of the column. But it is easily rectified after a little practice; and the traveller should learn to do this before starting on his journey. The thermometer must not be immersed in warm water, or otherwise heated, any such proceeding being attended with great risk, while it is rarely effectual. The following method is safe and certain. 1st, If the column is separated but the index remains in the spirit, grasp the instrument firmly by the upper end of the scale, taking care not to press on the tube; then, holding it at arm's length above the head, swing it down with a sudden jerk towards the feet, and repeat this till all the parts are reunited. Then let it stand half an hour, bulb downwards, to allow the last film of spirit to drain from the tube. 2nd, If the index has left the spirit and become fixed in the upper part of the tube, first grasp the instrument by the bulb end, and, proceeding as just directed, pass about half the column to the upper end of the tube. Having thus released and reimmersed the index, reverse the instrument and pass spirit and index back together. 3rd, If an air bubble has penetrated to the bulb, hold the instrument upright and strike the bottom of the scale smartly on the

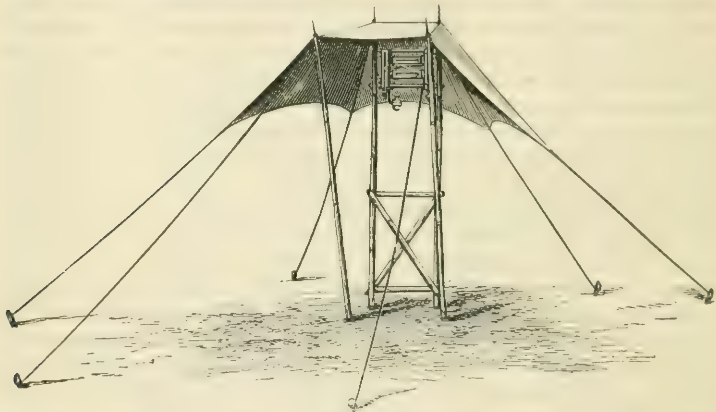
palm of the left hand repeatedly, until the whole of the air is driven into the tube. Then proceed as before for reuniting the column. Sometimes, when in use, a drop of colourless spirit, separated by evaporation, becomes lodged at the upper end of the tube, causing the thermometer to give too low a reading; and this may escape observation unless carefully looked for. Before suspending the thermometer, and also before taking a reading, the tube should always be closely examined to ascertain that the column is entire. Mercurial thermometers are much less liable to derangement.

The hygrometer should consist of two separate thermometers (not mounted on the same frame), and they should be suspended not less than 6 inches apart. The wet bulb should be provided with a small bottle having a narrow neck for the water supply (not an open cup). The muslin and wick should be renewed as often as they become dirty. The dry bulb serves to show the temperature of the air at the time of reading, and the difference of its reading and that of the wet bulb affords the data for computing the humidity of the air. The hygrometer can only be used for camp observations. For observations on the march, one of the sling thermometers should be fitted with muslin as a wet bulb. These thermometers being without attached scales are very portable. Each should have its own case, of thin brass tube closed at each end, and india-rubber lined, with a plug of cotton at top and bottom.

Every thermometer should be furnished with a table of corrections for all parts of its scale. The verification can be effected at the Kew Observatory on payment of a small fee. It cannot, however, be assumed that the corrections thus determined will remain constant, since thermometers undergo a slow change that may continue for many years. But as this change affects all parts of the scale equally, when an instrument has once been verified throughout, it is sufficient at any subsequent time to reverify its freezing-point, by immersing the bulb and lower part of the scale in crushed, melting ice. Any change, thus determined in the correction of the freezing-point, may be applied as a further correction to all parts of the scale.

Travellers in Arctic and Antarctic regions, in Siberia and Canada, in the winter, in any country indeed in which the temperature often falls below 0° Fahr., should employ spirit thermometers only, and these should be verified down to the freezing-point of mercury (— 37·9°). This too may be effected at Kew.

The reading of a thermometer may vary many degrees at one and the same place and time, according to the mode of exposure. If hung without protection, it will be unduly heated in the day-time, and unduly cooled at night, and if inside a tent it will probably not show the full range of the air's temperature. If, then, circumstances admit of the traveller's taking with him a light screen for the suspension of the maximum and minimum thermometers and the hygrometer, it is very desirable to do so. The accompanying figure represents such a screen, 5 ft. high, suitable for countries where the winds are moderate or light, such as are most tropical countries. It is constructed of bamboos or rods of



light wood, cords and canvas, which may easily be made up before starting, and it is easily renewed or repaired. The canvas roof should be triple or quadruple according to the thickness of the material. Such a screen will afford sufficient protection at night, or even in the day, if set up in the shade, and it will throw off rain ; but in the sun it will require a thick mat as an additional protection on the roof. A light frame between the uprights carries the instruments.

The chief advantage of this form of screen is its portability, and it is suitable only for camp use. Wherever an observatory can be set up for some weeks or months, the best form of screen is a louvred box, with a

double roof, having an air-space between the roofs. This should be fixed to four posts firmly planted in the ground; the door, which should also be louvred, opening on the side away from the sun.

The best form of rain-gauge is that known as Symons', with a receiving funnel 5 in. in diameter. But if it be important to reduce the size to the lowest limit for the sake of portability, a large bottle with a funnel of 3 or even 2 inches diameter screwed on the neck will give fairly good results. The size of the bottle will depend on the average heaviness of the rainfall in the country visited. In the tropics during the rainy season 3 or 4 inches in the twenty-four hours is by no means unfrequent, and sometimes as much as this may fall within an hour, and 35 inches in a single day have been recorded on the plains of Northern India; but in most extra-tropical countries 2 inches in twenty-four hours is an unusual fall. A bottle or other receiver that will hold 6 inches of rainfall will suffice in most places, the contents being measured and emptied once a day; and, in the event of any fall exceeding this, care must be taken to measure it more frequently. The funnel, if not exceeding 3 inches diameter, may be of brass. If larger, its mouth should be strengthened with a stout brass ring, to prevent deformation. Any alteration of its form diminishes its size, and therefore falsifies the record. The glass in which the rainfall is measured must be graduated to suit the size of the funnel; but, in case of accident, any truly graduated glass, such as an apothecary's 2 oz. or 4 oz. glass, may be substituted, and the rainfall being recorded as fluid ounces, drachms, &c., may be converted into inches by a simple calculation, the diameter of the funnel being known.

The most convenient form of barometer for travelling is the pocket aneroid. Those by the best makers give fairly constant readings, but no aneroid can be depended on as unchangeable. It should be compared with a standard mercurial barometer as late as possible before starting, and recompared, as often as opportunity may offer, with any mercurial barometer, the correction of which to the Kew or some other acknowledged standard is known. Comparison with an uncorrected mercurial barometer is of little use, since all mercurial barometers have some small scale error, and some a large error. The comparison should be made with the reading of the mercurial barometer, corrected for temperature (to the freezing-point), and reduced to the standard value, and the correction thus determined should be applied to all the aneroid

readings. An aneroid should not require any temperature correction, if compensated.

Any correction thus determined holds good, however, only so long as the instrument is exposed only to temporary variations of pressure, the average pressure being not greatly changed. It has been ascertained by Mr. Whymper that when an aneroid is subjected to a great reduction or increase or decrease of pressure, and so kept for many days, its error gradually augments, until it may become two or three times as great as when the change was first effected. If, therefore, the traveller remains long on a high plateau or mountain range, his aneroid will continue falling quite independently of any further reduction of atmospheric pressure; and in like manner when after such sojourn he returns to low altitudes, some weeks will elapse before the instrument recovers its original average readings at the higher pressure, and it may be found to have undergone a permanent change. The readings of an aneroid are therefore to be depended on only so long as it has not been exposed to great differences of pressure for prolonged periods.

Barometric observations.—Before reading a mercurial barometer, care must be taken that the instrument is quite vertical, which will be the case if it is suspended freely from the top, or in gimbals on an axis 3 or 4 inches above its centre of gravity. It must have a uniform temperature, to ensure which it ought to be suspended in the shade for at least half an hour before reading. The mercury-level of the cistern must be adjusted to the fiducial point at each reading, and in setting the vernier the eye must be exactly on the level of the top of the column to avoid errors of parallax. The reading of the thermometer attached to the barometer must always be noted simultaneously with that of the scale and vernier, as this is required to correct the reading for temperature.

In taking readings of an aneroid, the instrument should always have the same position, preferably the horizontal, and the eye must be vertically over the index. If it has been at rest for some time previous to reading, the case should be gently tapped with the finger before reading.

The variations in the readings of a barometer transported from place to place in the course of a land journey are influenced both by changes of elevation, and by those of the weather, the effects of the former being, in general, much more considerable than those of the latter. If, then, the

barometer is used for the purpose of ascertaining elevation, no great accuracy can be expected, unless the effect of weather-changes can be ascertained and eliminated, and this is only possible, even in an approximate degree, when its readings can be compared with those made simultaneously at some not very distant station of reference, the elevation of which is known. And, on the other hand, unless the elevation of the station of observation is accurately known (or the average barometric reading of the site and season of the year) the barometer is useless as a weather glass, except in so far as any conclusion can be based on the simple fact of a rise or fall between consecutive readings at the same place. Hence, in travelling through a country far distant from any fixed observatory, the barometer is used chiefly for hypsometrical purposes, and in computing elevations it is necessary to assume a mean barometric value at the sea-level. This is generally taken at 30 inches; but this assumption sometimes involves a large error, which may seriously vitiate the computed result. Especially is this the case in the interior of great continents, particularly Asia, when the mean sea-level value of the atmospheric pressure in July is more than an inch below the mean of January, an amount of change which would be produced by an ascent through about 1000 feet.

In such cases it would much improve hypsometrical determinations if, instead of assuming the constant value of 30 inches for the sea-level datum, its value be taken from a barometric chart showing the average distribution of atmospheric pressure for the month of observation in that part of the world. Several such charts have now been published, the latest and probably the best being those drawn up by Professor Hann, and published in the recent edition of Berghaus's 'Physical Atlas.' These include charts of the average distribution of pressure for January and July, and since these represent the extreme phases of the annual oscillation, the values for other months obtained by interpolation will involve only a small error in most parts of the Northern Hemisphere. But for the interior of Australia, Africa, and South America there exist no data for compiling such charts, and the best assumption that can be made is that, about the time of the equinoxes, the sea-level pressure on these continents is probably about the same as in the same latitudes on the ocean, two- or three-tenths lower in the heart of the country in January (midsummer) and as much higher in July (midwinter).

Between the tropics, the oscillations of the barometer with irregular changes of weather, except during the passage of a cyclone, are comparatively small; in general not exceeding from one- to two-tenths above or below the average (equivalent to one or two hundred feet of elevation); but in the temperate and arctic zones they often amount to upwards of an inch, and in these parts of the world barometric determinations of heights from isolated readings are subject to uncertainty through a large range of possible error, unless the simultaneous observations of fixed stations, laid down on weather charts, supply the means of correction. These oscillations are greater in winter than in summer. The longer the period over which the observations extend, the smaller will be the probable error of the computed result.

In all parts of the world, except perhaps in the neighbourhood of the poles, the barometer has a regular daily oscillation, independently of the weather. Except, however, in the tropical and sub-tropical zones (say between 40° N. lat. and 30° S. lat. over continents and within narrower limits on the ocean), this oscillation is too small to need special attention in hypsometrical determinations, especially if the far greater irregular oscillations are unknown. In the tropics, however, it is both absolutely and relatively more important, and should be taken into account, both in computing elevations and in interpreting the barometric changes with reference to the weather. The barometer rises from 3 or 4 A.M. to between 9 and 10 A.M., then falls to between 4 and 5 P.M., rises again to 10 P.M., and again falls till about 3 A.M. Where greatest, as in Southern India, the fall from the forenoon to the afternoon amounts to about $\frac{3}{20}$ of an inch; the other changes are less, but the exact amount and also their relative amounts vary not only with the latitude, but under the same latitude from place to place. In valleys between mountains, the midday fall is greater than on plains, and on mountain peaks and crests considerably less, and in these latter positions the barometer stands higher before midnight than at any other epoch of the twenty-four hours. Some data on this head are given in the section on hypsometry. On the sea, the night and day oscillations are more nearly equal than on land.

Temperature observations.—The readings of thermometers are understood to show the temperature of the air, and the sling thermometer does this very nearly, even in the sunshine, and very accurately in the shade. But thermometers suspended and at rest are affected by radiation from

all objects round about them, and these may raise their temperature in the daytime above that of the air, and unduly lower it at night. They must in any case be fully screened from the sun and the sky, and from any strong reflection of sunlight, and at the same time the air must be allowed to pass over them freely. Inside a tent, the night temperature will generally be higher than that of the air outside; in the daytime it may be higher or lower, according to circumstances, but it will rarely be the same. The use of the screen, described above, is to afford a tolerably uniform exposure, and a sufficient, but not excessive, protection. In order to ascertain how far it fulfils this purpose, simultaneous readings should sometimes be taken with the sling thermometer and the suspended thermometers, and the two compared. The results of such comparisons should always be entered in the register.

The thermometers should always be suspended at the same height above the ground. In the warmer hours of the day, when the sun is shining, the ground and the air in contact with it are much warmer than that a little distance above it, and the temperature decreases rapidly within the first few feet; while at night time, and especially on clear nights, the reverse holds good. The use of the screen ensures uniformity in this respect also.

Readings of the self-registering thermometers can be made only in camp or at a halting station. In settled weather, and almost invariably in tropical countries, the lowest temperature of the twenty-four hours occurs shortly before sunrise, and the highest from one to three hours after noon. As the maximum and minimum temperatures are understood to be the extremes of the twenty-four hours, implying that the instruments have been exposed throughout this period, if such is not the case, the fact should be noted against the reading, together with the hours of exposure.

In addition to the maximum and minimum temperatures, it is desirable to take readings of the actual temperature at certain fixed hours. The best hours are either 6 A.M. and 2 and 10 P.M., or 7 A.M. and 2 and 9 P.M., these being the hours that are very generally observed at regular observatories, and having the further advantage that the arithmetical mean of the three readings is, on an average, very nearly the true mean temperature of the day. But whatever hours are selected should be regularly adhered to, so that the readings of different days may be comparable with each other.

In camp, the air temperature reading may be taken from the dry bulb of the hygrometer or the sling thermometer, or both. On the march, the latter instrument alone should be used.

The use of the sling thermometer is as follows. Each thermometer has a string a couple of feet long attached to a glass ring at the upper end of the tube; the end of this being secured by a few turns round the finger, the instrument is swung round a dozen times or so and rapidly read off. It is then again swung and the reading repeated, and so on, until the reading remains constant, and this final value is entered in the note-book. It is best to select shade for this purpose, but it is the peculiar advantage of the sling thermometer that its indications are but little affected by the sun.

The temperature of the air is much influenced by the character of the site; and this should always be noted in the register. On hill summits and hill ridges the diurnal range of temperature is less than on a plain, and considerably less than in a narrow valley. Hence at night, and especially in the winter, it is often warmer a few hundred feet up a hill-side than at lower levels. More particularly is this the case in a still atmosphere. In certain mountainous countries, the winter temperature in a valley may be no higher than at 5000 feet above it, and lower than at all intermediate elevations. With these exceptions, the temperature generally decreases with elevation, but the ratio is very variable. On mountains the average rate of decrement is 3° in every 1000 feet, but in rainy weather it is often less than this, and in hot, dry weather, especially if a Föhn wind is blowing, it may be as much as 4° or 5° in the 1000 feet. On plains and table-lands it varies as a rule between 2° and 3° per 1000 feet.

In respect of temperature the most important elements of climate are:—

1st. The mean temperature of the year, and of each month.

2nd. The annual range of temperature, which may be expressed either as the difference of the highest and lowest readings in the year or that of the mean temperatures of the warmest and coolest months.

3rd. The extreme temperatures of each month and their difference, *i.e.*, the monthly range.

4th. The mean daily range, and the greatest in each month.

5th. The variability of temperature, which, in the case of observations extending over short periods, is best shown by the amount of the mean change from day to day, *i.e.*, the average difference of the mean temperatures of consecutive days.

Most of these data express conditions that have an important influence on vegetable life and almost equally so on human health and comfort. The real annual and monthly mean temperatures can of course be ascertained accurately only from many years' registers. But, in most places, an approximation to the mean annual temperature may sometimes be obtained by taking the temperature of perennial springs, fed by percolation from the surface (not mineral springs).

In connection with non-periodical changes of temperature, it should be noted how they are related to changes of wind. This relation may be different at different seasons. Thus, in Northern India, the West and North-west winds are the cooler winds of the winter months, but the hot winds of the spring and summer.

Humidity observations.—The observations of the dry and wet bulb thermometers may be made either with the hygrometer suspended in the screen, or with the sling thermometers, as already described; the wet bulb being swung slowly, and, if necessary, re-wetted between each swinging. The hours of observation should be the same as for temperature; and the mean of the three values computed from each pair of observations separately will be very nearly the true mean of the twenty-four hours.

In a calm atmosphere some care is necessary to obtain trustworthy readings of the wet-bulb thermometer. A single thickness of muslin should be fitted closely over the bulb, and both it and the wick that supplies it with water should be quite clean, and especially free from grease, in order that they may take up the water readily and remain wet, however rapid the evaporation. The softest and purest water obtainable should be used, since hard water gradually deposits a stony encrustation, which is removed with difficulty. The air must not stagnate around the hygrometer, since, in still air, the wet bulb gives too high a reading.

From the simultaneous readings of the dry and wet bulb thermometers

(duly corrected for the errors of the instruments) the humidity of the air is deduced by a simple computation. It may be expressed in four different ways. First, as the pressure of the vapour present in the air (expressed in decimals of an inch of mercury); second, as the weight (grains) of vapour in each cubic foot of air; third, as the dew-point of the air, or that temperature at which the vapour would begin to condense; and fourth, as a percentage of the quantity that would saturate the air at the observed temperature. The first three express the *absolute*, the last the *relative* humidity. The last is perhaps most important in relation to the weather, and as affecting vegetation and bodily comfort.

The pressure of the vapour in the air may be computed by the following formula, in which t and t', are the corrected readings of the dry and wet-bulb thermometers respectively, f the tension of saturated vapour at temperature t, to be taken from the table at the end of this section, and h the height of the barometer. For this last, a rough approximation (to the nearest inch) is sufficient. For wet-bulb temperatures above 32°, the formula is

$$F = f - \frac{0{\cdot}480\,(t - t')}{1130 - t'}\,h,$$

and for those below 32°

$$F = f - \frac{0{\cdot}480\,(t - t')}{1240{\cdot}2 - t'}\,h,$$

F is the tension of the vapour present in the air. This being computed, the relative humidity is given by the formula

$$R.H. = \frac{F\;100}{f}.$$

Numerous tables are published by which the observer may be saved the labour of computing both these values.

Professor Nordenskiold is of opinion that in Arctic climates, with the temperature far below the freezing-point, the ordinary hygrometers do not give trustworthy results. When exposed in the usual way in a louvred box, it is impossible to keep the case clear of snow, and thus the air, which may have been originally quite dry, must here be saturated with moisture from the evaporation of the snow. He recommends, therefore, that in order to determine the true humidity, future travellers to

these regions should weigh the water which a given measure of air contains, by passing a measured quantity through tubes containing some desiccating substance, such as dehydrated sulphate of copper or pumice soaked in sulphuric acid. This requires a delicate balance, in addition to the aspirator and absorption tubes, and can, of course, only be carried out conveniently either on board a ship or at an observatory temporarily established on land, but it has the advantage that, by means of a tube of sufficient length, the air to be tested can be drawn from any required height above the surface, at such a height as to be above the influence of the snow dust that whirls about near the ground surface. The use of this apparatus, which is very simple, should be learned in a physical laboratory.

The humidity of the air varies with small changes of site and elevation even more than the temperature, especially in the neighbourhood of sheets of water, swamps, etc. In mountain tracts, with greater changes of elevation, the relative humidity, as a rule, increases gradually with the height, while the absolute humidity generally decreases. In settled weather the relative humidity is greatest when the temperature is lowest (viz., just before sunrise), and lowest at the hottest hours of the day, varying inversely as the temperature. The absolute humidity is highest in the early afternoon in damp climates, in dry climates usually in the evening. It often varies with the wind direction in a very marked degree, even in the interior of continents, and all such changes should be especially noted.

Rain, snow, hail, dew, &c.—The rain-gauge must be exposed in an open place, as far as possible from trees, and not too near a tent. The aperture of the funnel should be quite level and about 1 foot above the ground. For obvious reasons it is desirable to surround it with a temporary fence, at a distance of at least three feet when not exceeding three feet in height. A gauge of 5 inches diameter and upwards will serve to collect a small fall of snow, and, when melted, the snow water is measured as rain; but with a heavy fall the funnel soon becomes choked, and collects no more. In this case, if the gauge has a cylindrical receiver of the same diameter as the funnel, it may be inverted over the snow, where not drifted or otherwise disturbed, and pressed down so as to cut out a cylindrical mass of the thickness of the sheet, which may be melted and measured in the usual way. Failing

this, the thickness of the snow, where undisturbed, may be gauged with a 2-foot rule, and each foot of snow counted as 1 inch of rainfall. This ratio is approximately valid, when the measurement is taken immediately after the fall, but even then is only a rough approximation.

In the case of hail, the form, size, and internal structure of the hailstones should be noted, and, if possible, sketches should be made of some of the largest as soon as possible after their fall, and before they have had time to melt. The forms of hailstones are very various, and their mode of formation is still far from being satisfactorily explained.

The hours of rainfall, &c., should be noted in the register. In the tropics, there is often a very decided tendency to rain at certain hours of the day or night, differing at different seasons of the year. The time of least frequency is the hour or two before midnight. The quantity that falls in short intervals of time, such as an hour or less, is also a very marked feature of certain climates.

In nearly all parts of the world there is more rain, snow, hail, &c., at certain seasons of the year than at others, and in most tropical countries this annual variation is very marked. Wherever this is the case, the seasons of ploughing, sowing, transplanting, &c. crops, are determined by that of the rainfall, and where there is more than one rainy season certain crops are special to each. It should always be ascertained, if possible, what are the usual seasons of rain and their duration; also what characteristic changes of wind accompany rain and dry weather respectively.

Mountain ranges exert a very important influence on the distribution of rain. Whatever be the characteristic direction of the damp wind, the rain is heaviest on the windward face of the range and the plains at its foot, and often entirely restricted to them; the quantity and frequency of the falls increasing with proximity to the mountains, and in the case of lofty ranges reaching a maximum at a certain elevation, above which it decreases. In India and Java this elevation is between 3000 and 4000 feet; in England apparently about 1500 feet. Wherever possible, it is important to ascertain this height, which may be approximately indicated by the character of the vegetation. In snowy ranges the height above which snow remains unmelted throughout the summer

should also be ascertained, bearing in mind that glaciers often descend much below this limit.

The occurrence of dew should always be noted in the register. Its quantity may be roughly estimated as light or heavy, or it may be measured by exposing a weighed mass of dry wool or cotton-wool spread over a surface of definite dimensions, and re-weighing after exposure; but this requires a delicate balance, and the observation is of a kind more suited to the means and appliances of a fixed observatory than to those of the traveller.

Winds.—The direction of the wind may be easily obtained by a pennant or flag, the drift of smoke, or better than either, by observing the movement of low clouds with a compass. In order to do this accurately, select some prominent object, such as a tree-top or the top of the tent-pole, and take up a position such that the apparent movement of the cloud is either directly downwards towards it or directly up from it. Then the direction of the tree or pole as taken by the compass is that towards which the cloud moves in the former and from which it travels in the latter case. Generally the surface-wind blows from a point a few degrees to the left of that indicated by low clouds in the Northern Hemisphere; to the right in the Southern Hemisphere. At night the movement of the clouds across the face of the moon affords a good means of observation.

A very important class of observations, which should be recorded as often as opportunity may serve, is the movements of the high cirrus or feather cloud. This may be observed in the same way as that of the lower clouds; but the observation takes longer, since, owing to the great elevation of the cirrus, its apparent movement is very slow. These clouds show the movements of the atmosphere at elevations of 30,000 feet and upwards—movements which are much less variable than those of the surface winds; and a knowledge of the directions prevalent in different parts of the world is much required for determining the greater and more persistent movements of the atmosphere.

Another method of observing the movements of clouds, both high and low, with ease and great accuracy, is by using a portable nephescope. This consists of a plate of thick glass, about 1 foot in diameter, having two lines engraved across its surface, and rubbed in with white paint, to indicate the four cardinal points. The glass is blackened on the back

and mounted in a light brass frame, which is supported by three adjustable screws for levelling. A small pocket spirit-level is carried with the instrument, and also a small leaden disk with a vertical pin about an inch high fixed to its margin. To observe with this instrument, the mirror is levelled and adjusted in azimuth, and, a small cloud having been selected, the observer takes up a position such that its reflection coincides with the cross-lines in the centre of the mirror. The disc is then placed on the mirror so that the point of the pin is between the eye and the cross. When sufficient time has elapsed for the cloud reflection to have travelled some little distance across the mirror, the observer takes up the same position as at first, which the pin and cross-lines enable him to do accurately. The direction in which the image has travelled across the mirror is accurately that of the cloud's movement.

The force of the wind on land may be estimated as, 1, Calm; 2, Light; 3, Moderate; 4, Fresh; 5, Strong; 6, Gale, and noted in the corresponding numbers. At sea, a more definite scale extending to 12 numbers, known as *Beaufort's Numbers,* is employed, but this is hardly applicable on land, except on the coast. Their approximate values in miles per hour are as follow:—

0. Calm . . .	0 to 5 miles per hour
1. Light air . .	6 to 10 ,, ,,
2. Light breeze .	11 to 15 ,, ,,
3. Gentle breeze .	16 to 20 ,, ,,
4. Moderate breeze .	21 to 25 ,, ,,
5. Fresh breeze .	26 to 30 ,, ,,
6. Strong breeze .	31 to 36 ,, ,,
7. Moderate gale .	37 to 44 ,, ,,
8. Fresh gale . .	45 to 52 ,, ,,
9. Strong gale . .	53 to 60 ,, ,,
10. Whole gale . .	61 to 69 ,, ,,
11. Storm . . .	70 to 80 ,, ,,
12. Hurricane . .	80 miles and upwards per hour.

At most places, the winds undergo a more or less regular variation in the course of day, and at some this is sufficiently marked to be obvious to the casual observer. It may affect the rate of movement or the direction, or both. All such instances are worthy of being noted, together

with the hours at which the changes occur, the local geographical features that influence them, and the character of the weather when they are most developed, and when they are suppressed. The traveller should also ascertain what winds are most prevalent at each season, and their character as damp or dry, hot or cold.

At some localities, chiefly in the neighbourhood of mountain ranges, very strong but dry winds, sometimes accompanied with fine weather, blow at certain seasons of the year, but only in certain states of the atmosphere. Such are the *Föhn* in Switzerland and the Tyrol, the *Bora* in the Adriatic, and the *Mistral* at the mouths of the Rhone and on the northern coast of the Gulf of Genoa. The first of these is a warm, dry wind, the second much less warm, and the third, though dry, very cold. The *Föhn* and the *Bora* blow down from mountains, and are heated more or less in virtue of the compression which the air undergoes in descending from the higher to the lower level. There is reason to believe that similar strong winds are experienced in the neighbourhood of other mountain chains in temperate and Arctic climates, and indeed such have been described both in Greenland and the Caucasus. The *Mistral*, which blows in the winter and spring, owes its stormy character to the juxtaposition of the cold plains of Central and Southern France and the relatively warm Mediterranean Sea; and it is restricted to the lower course of the Rhone and the coasts of the Gulf of Genoa. A stormy wind of the opposite character blowing from the cooler sea to the heated land is common in the spring in the north of the Bay of Bengal. All such cases should be noted by the traveller.

State of the sky and atmosphere, Cloud, &c.—The cloudiness or serenity of the sky is most conveniently recorded by estimating the proportion that is covered with cloud as so many tenths of the expanse included within 60° of the zenith, or within two-thirds of the total distance between the zenith and the horizon. The zone within 30° of the horizon is excluded, since distant clouds are foreshortened in plan, and cannot be estimated on the same scale as those overhead. The quantity is recorded in the numbers 0 to 10, zero indicating a cloudless sky, and 10 one entirely overcast. In this estimate, clouds of all kinds and at all elevations are included indiscriminately, and it is desirable, therefore, at the same time, to note the leading characters of the clouds, since certain forms are characteristic of fine weather, while others portend unsettled weather. This distinction is

taken as the basis of the scheme of cloud classification drawn up by Messrs. Hildebrandsson and Archibald, which is as follows:—

α. *Discrete tending to rounded forms (principally in dry weather).*	β. *Extended and sheet-like forms (rainy weather).*
A. Highest clouds, mean height 30,000 feet.	
1. Fibre cloud [*Cirrus* or mare's tail].	2. Thin cloud veil [*Cirro stratus*].
B. Medium elevation 13,000 to 20,000 feet.	
3. Small globular cloudlets, shining white like silk, 20,000 feet [*Cirro-cumulus*, mackerel sky]. 4. Larger globular, like white wool, 13,000 feet [*Cumulo-cirrus*].	5. Thicker ash-coloured, or bluish-grey sheet, 17,000 feet [*Strato-cirrus*].
C. Lower clouds, 5000 to 7000 feet.	
6. Great rounded masses or rolls of grey cloud [*Strato-cumulus*].	7. Ragged sheets of grey cloud from which rain commonly falls [*Nimbus*].

D. Clouds in ascending air currents.

8. Heap cloud [*Cumulus*]. Summits at 6000 feet. Bases at 4500 feet.
9. Storm (thunder) clouds [*Cumulo-nimbus*]. Summits 10,000 to 16,000 feet, bases 4500 feet.

E. Elevated fogs. Below 3500 feet [*Stratus*].

The elevations given are furnished by measurements made in Northern Europe, and would probably differ in other latitudes, being greater in the tropics. But Mr. Abercromby finds, as the result of his wide experience in different parts of the world, that cloud forms are much the same everywhere, save only that some forms are more prevalent in lower and others in higher latitudes.

Fogs, as is well known, are restricted to damp climates and cold weather; but sometimes they present peculiarities that are worthy of

attention. A remarkable instance of the kind occurs in Assam, where, in the cold season, the atmosphere often remains perfectly clear till about half an hour after sunrise, when, in the course of a few minutes, everything is obscured by a thick fog, which may remain undissipated for some hours. The writer is not aware of a similar phenomenon having been recorded elsewhere.

In some very dry countries where fogs are unknown, the atmosphere is nevertheless frequently or even constantly obscured by a more or less dense haze up to heights of many thousands of feet. Such is the case in the dry season in Northern India, and in the almost rainless region of Yarkand and Kashgar, it is described as being constantly so thick that, according to Dr. Henderson, hills only five miles distant are barely visible; and Mr. Shaw also states that the Pamir mountains, at the distance of twelve miles, appear to be a distant range of which the outline only is distinguishable. On the other hand, in the almost equally dry salt desert (*Kavir*) of Persia, the atmosphere is usually remarkably clear. There can hardly be much doubt that the haze consists of fine dust, but the conditions which determine its prevalence in some countries and its absence in others, deserve more attention than they have yet received.

Storms.—In the case of storms, we must distinguish between temporary squalls (thunder-storms with or without hail, dust-storms, &c.), such as occur chiefly in hot summer weather in all parts of the world, and especially in the tropics, and those more extensive disturbances, which are marked by a more or less considerable depression of the barometer, which often travel some thousands of miles over land and sea, and on tropical seas develop into those formidable and destructive storms, long known as hurricanes in the West Indies, as typhoons in the China seas, and generally during the last thirty or forty years as cyclones. Tornadoes or whirl-winds, cloud-bursts and water-spouts which, within restricted limits, are even fiercer and more destructive than tropical cyclones, appear to be essentially related to the former in their mode of origin, though the whirling of the air, which is one of their chief characteristics, has led many writers to class them with the latter; but the blizzards of the Northern American States and their Asiatic counterparts, and the *Buran* or *Purga* of the Siberian tundras, are a severe winter form of the storms of the cyclonic class.

Thunder-squalls appear to be local eddies of the atmosphere, but

there is yet much to be learned respecting their mode of origin, and the circumstances that give rise to them. In many cases, and especially those of the more severe forms, they appear to be determined by the juxtaposition of a cold and dry with a warm and damp air current. Such has been shown by Lieut. Finlay to be the condition that always accompanies the destructive tornadoes of the United States, and it probably holds good also in Bengal, where, however, tornadoes are comparatively infrequent. The nor'-westers of Bengal and the dust-storms of North-western India are also probably due to the existence of a dry and comparatively cool air current above, and a warm damp atmosphere at the earth's surface. These and similar squalls of the temperate zone are preceded by strong, sometimes violent, gusts of wind blowing outwards from beneath the storm-cloud, and also by a rapid rise, followed by irregular oscillation of the barometer. Hail sometimes falls in these squalls, as a rule from the front part of the storm, succeeding the gusts, and in these cases a peculiar sound is often heard on the approach of the storm, which is generally attributed to the hurtling of the hail-stones in the storm-cloud. The formation of hail is far from being satisfactorily explained. The most probable hypothesis is that of Professor Ferrel, viz., that there is in the storm-cloud a violent eddying uprush of air of the nature of a tornado, and that the hail-stones formed by the dynamic cooling and condensation of the vapour thus carried up, after being thrown off from the summit of the eddy, are caught up again and again and enlarged by further condensation, until they attain such a size as to escape the indraught around the vortex. Observations on the temperature and humidity of the air, taken at short intervals (such as five minutes) on the approach of a thunderstorm, and those of the general and internal movements of the storm, that will help to throw light on the genesis of hail, may be of much value. A similar remark applies to the rarer phenomena of water-spouts and tornadoes. The direction of their internal movement should also, if possible, be noted, whether clockwise or anti-clockwise.

In the case of the more extensive cyclonic storms, the extension of our present knowledge is to be looked for chiefly from the greater development of the system of weather charts. These of course cannot be constructed from the isolated observations of a traveller, but it may sometimes happen that such observations may furnish a useful link in the evidence elsewhere

furnished by permanent observations or by ships. Where the ravages of a cyclone are visible in fallen trees or other objects it may be useful to note the compass direction of their fall, as an indication of the wind direction when strongest. And in the neighbourhood of the sea-coast, if the storm has been accompanied by a storm-wave, which has flooded the land, the height of the inundation should be ascertained from the marks left on trees, buildings, &c.

Special observations—There are many subjects connected with meteorology and the physics of the atmosphere, for the investigation of which other parts of the world afford more favourable conditions than are to be found in our own islands. Many of these, however, demand not only prolonged residence at the place of observation, but also a familiar acquaintance with physics and methods of physical experimentation, such as can only be gained by long study and practice; and any notice of them would be beyond the scope of these hints. But there are one or two subjects of inquiry, to which, although somewhat special, travellers may contribute valuable information, and which demand nothing more than some time and attention, and such ordinary precautions as are implied in the proper use of even the simplest instruments.

Among the more important of these are the sun's heating-power, the temperature of the ground, and the diurnal variations of air-temperature and humidity, and the atmospheric pressure. On each of these a few suggestions will be offered.

The absolute measurement of the heat received from the sun, *i.e.* its quantity in terms of heat-units per second or other units of time, is a problem that has hardly yet been satisfactorily solved. Several forms of actinometer have been devised for the purpose, but it is at least doubtful whether any are free from serious error, while their use requires an amount of skill that demands long training; but even a good relative measurement, such as may be made with simple instruments, is of much value, and may be undertaken by any one who will devote some little pains to the subject. Especially is it desirable to obtain relative measurements at different elevations on mountains, and at different hours of the day; and as an element of climate the datum is one of great importance. For this purpose, the requisite instruments are two mercurial thermometers in vacuum tubes, the one having the bulb coated with lamp-black, the other uncoated. With this exception, the instru-

ments should be exactly similar in all respects; the bulbs and their enclosures of the same dimensions, thickness and materials, and exhausted to the same degree, to as high a vacuum as possible. They should not be self-registering, but made to read as ordinary mercurial thermometers, and they should be verified (as complete instruments) and furnished with tables of corrections. They should be exposed on a stand about 4 feet high, being about 6 inches apart, the bulbs free of the stand, so that they may be equally affected by all objects around. The instruments should be wiped with a soft cloth before exposure. An universal sun-dial is an useful adjunct.

The observations will consist of simultaneous readings of the two instruments, and a reading of the air temperature as shown by the ordinary shaded thermometer. The readings should be taken at apparent noon (as given by the 'Nautical Almanac,' or by a sun-dial truly adjusted for the magnetic variation, and at equal intervals, one, two hours, &c.), before and after, provided the sky is clear. The depth of the sky tint should be noted at the time of observation, and also the existence of haze and thin cirrus cloud, and the movement of the latter whether towards the sun or otherwise. These facts may be recorded according to the following notation, devised by Mr. Hennessey for the guidance of the actimometric observers at Leh:—

A—signifies a perfectly clear sky, or, if small patches of cloud be visible, they are not within 50° of the sun.

B—signifies that small patches of cloud are occasionally seen to rise, and float generally towards the sun; that they become invisible in certain positions not less than 30° from the sun, but that their tracks if continued would pass well *clear of the sun*.

C—has the same meaning as B, with the exception that the tracks point to the sun.

a—means no haze.

b—means that haze can be seen in the far distance, but only along a portion of the horizon.

c—means that haze is visible all round the horizon, or at any rate in opposite directions, but not overhead.

The numbers 1 to 4 are used to indicate blueness of the sky: 4 stands for deep blue, and 1 for pale blue-white, with 2 and 3 for intermediate tints.

The temperature of the ground surface may be taken with an ordinary mercurial thermometer (duly verified for error), laid on the ground slightly inclined, the bulb just immersed in the surface layer of soil, but not quite covered; this may be read just before sunrise and about 1 P.M., these being the times of minimum and maximum temperatures; also, if convenient, at intermediate hours; or maximum and minimum self-registering thermometers may be exposed in like manner, but in this latter case, the minimum (spirit) thermometer must be removed during the daytime, or it will probably burst with the high temperature of the heated ground. The spot for these observations must be unshaded at all hours of the day.

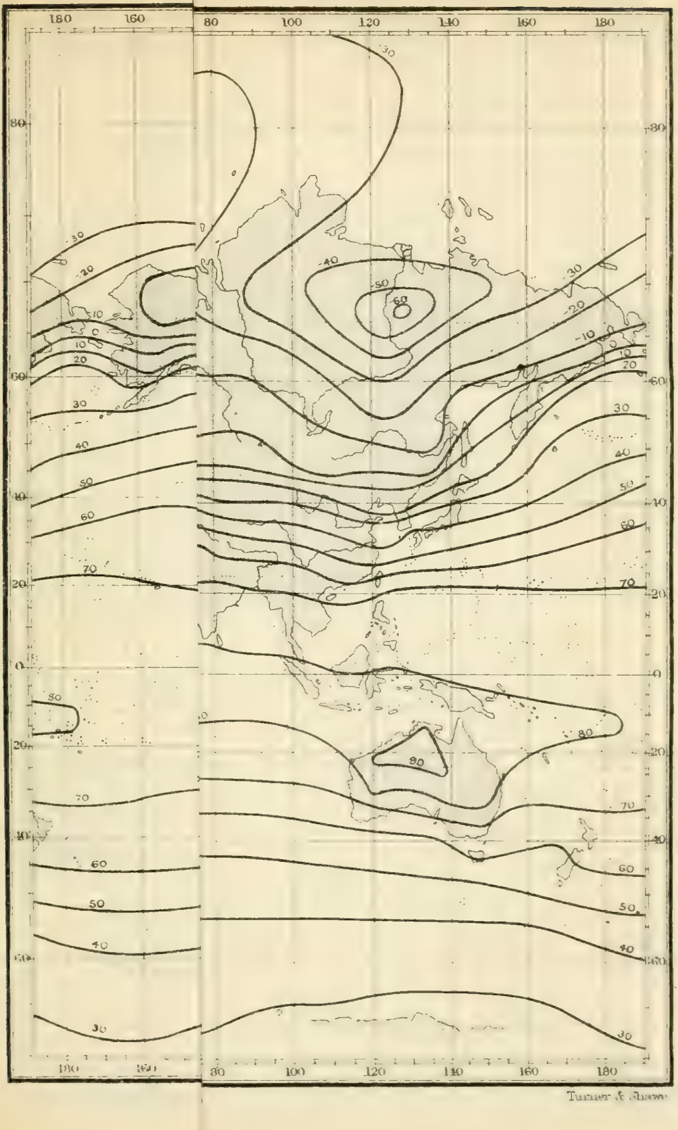
Temperature observations of the ground beneath the surface are valuable only when they can be continued for at least a twelvemonth at the same spot. In such cases it is desirable to obtain observations from a depth of about 3 feet 6 inches, which is about the limit, below which the diurnal variation becomes insensible, though, it must be remarked, this limit must vary with the conductivity of the soil and the amplitude of the daily variation at the surface. A good arrangement for obtaining such temperatures is to sink a square wooden tube to the required depth, leaving the end projecting 6 inches above the surface, the upper end being covered with a loosely-fitting wooden cap. In sinking the tube, care should be taken not to disturb the ground around, except on one side, and on that side not to a greater width than is necessary. The thermometer should have its bulb protected by a copper shoe, and should be sunk in the lower end of a wooden plug nearly as long as the tube, and nearly filling it. If the thermometer is merely suspended by a cord or wire, leaving the greater part of the tube unfilled, the circulation of air inside the tube will vitiate the observed temperatures. A thermometer mounted in the way described can be withdrawn and read without suffering any change, and it can then be replaced and left till the next reading. One reading a day, at a fixed hour, will suffice.

It is often stated that the mean annual temperature of the ground at any place (or its temperature at such a depth as to be just below the limit of any annual oscillation) is also the mean temperature of the atmosphere, excepting, of course, in the neighbourhood of hot springs, of active volcanoes, and similar disturbing causes. But this is by no

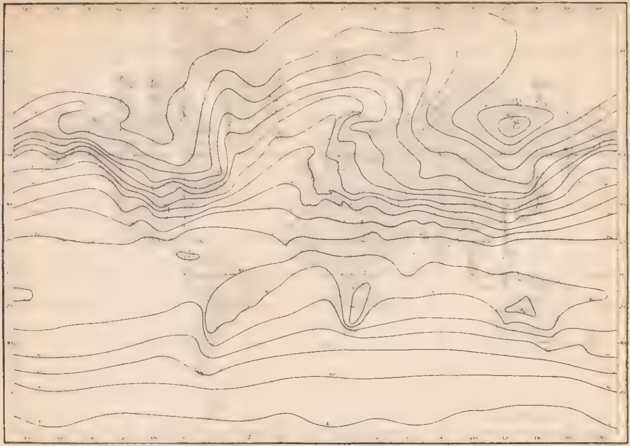
means always the case. It has been found that everywhere in India the ground temperature exceeds that of the air by amounts varying from 3° to 6°, and it is at least probable that, to some extent, a similar rule holds good generally in the tropics, the excess being greater in dry than in damp regions. For this reason, the temperature of such perennial springs as may be assumed to have the mean ground temperature cannot be always accepted as representing that of the atmosphere.

The observation of the diurnal variation of temperature, humidity, and other elements, especially the barometric pressure, is a very valuable contribution to meteorology. In tropical countries, where the diurnal variation is most considerable, even a few days' observations will show the leading features of the oscillation in fine weather; but the longer the period over which they extend, the more trustworthy is the result. Observations may be recorded either hourly or every two hours throughout the twenty-four hours, and, if not repeated on consecutive days, the first and last of every set of observations should be made at the same hour, so that each hourly set will comprise twenty-five readings, each bi-hourly thirteen readings. These observations will necessarily require that the work be shared by two or more observers, unless autographic instruments are employed. The barometric oscillation will be shown fairly well by a good self-recording aneroid, which marks the pressure continuously on a drum driven by clockwork; but this register should, if possible, be controlled by the readings of a mercurial barometer about the hours of maximum and minimum pressure. The larger self-recording instruments are suitable only for permanent observatories.

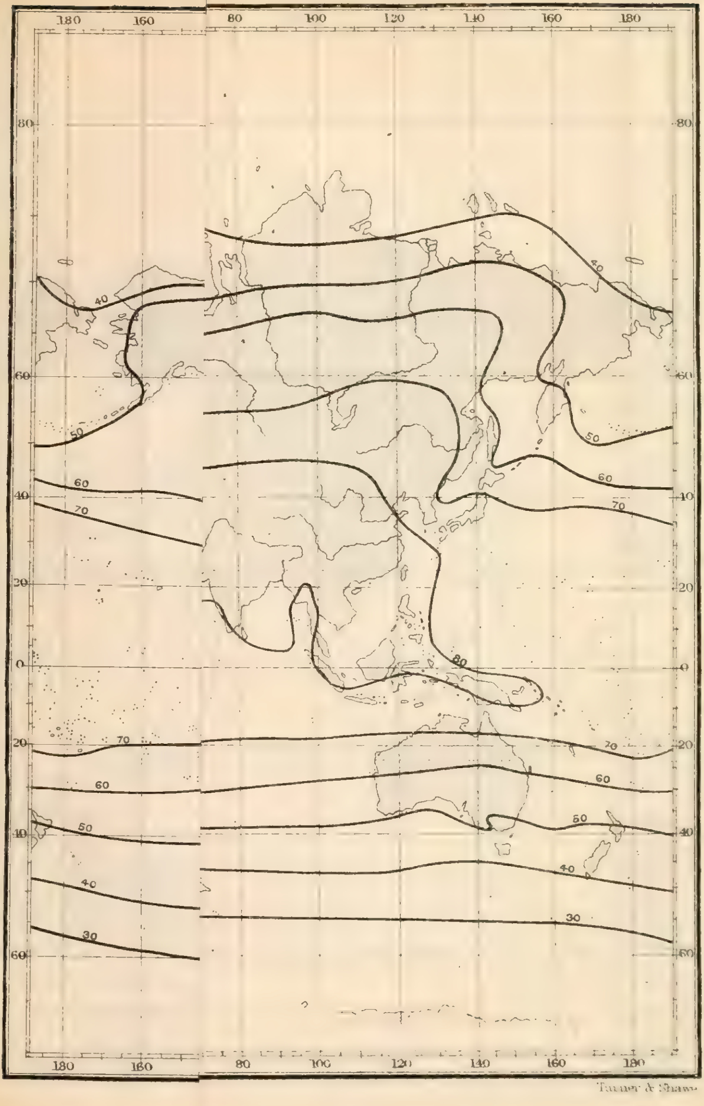
E GLOBE FOR JANUARY.



ISOTHERMAL LINES SHOWING THE MEAN TEMPERATURE (FAHR.) OF THE GLOBE FOR JANUARY

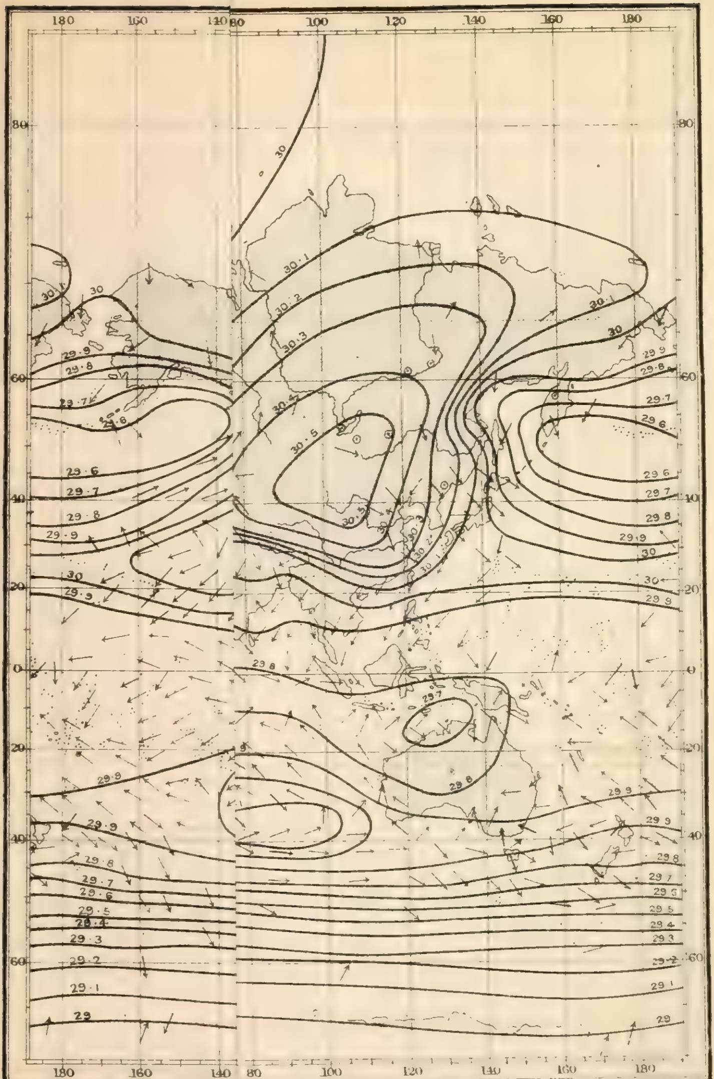


THE GLOBE FOR JULY.



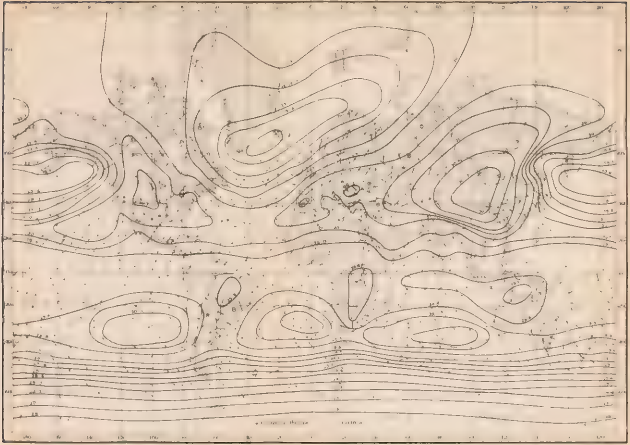
ISOTHERMAL LINES SHOWING THE MEAN TEMPERATURE FAHR OF THE GLOBE FOR JULY

FOR JANUARY.

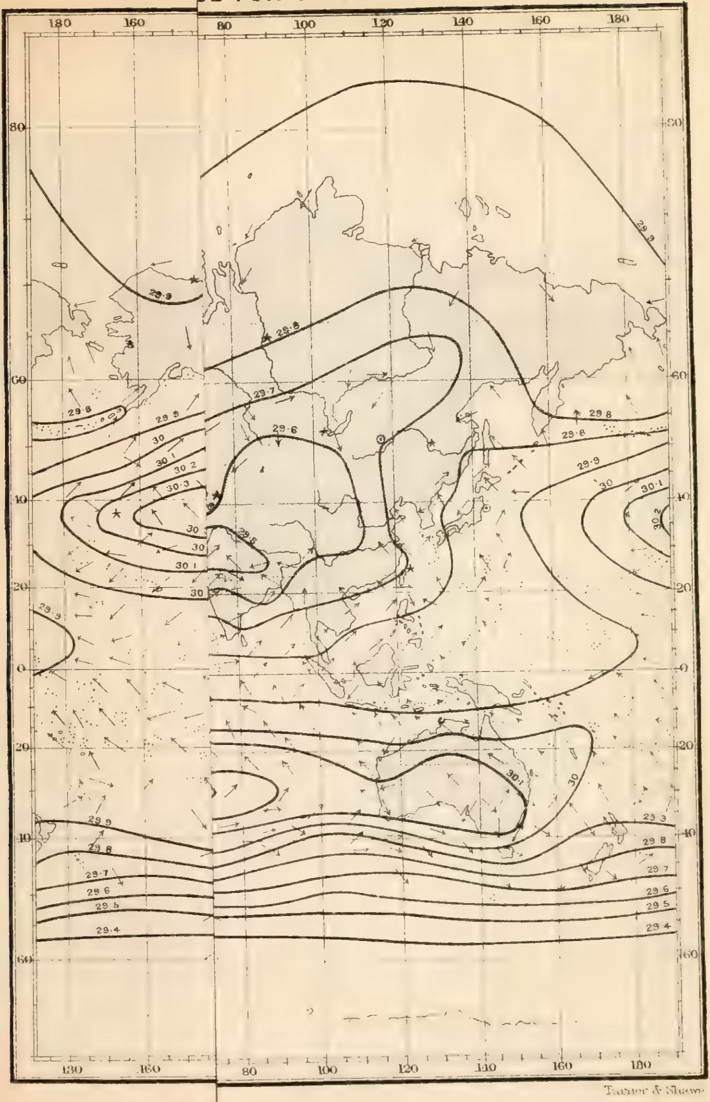


Turner & Shawe

ISOBARIC LINES AND PREVAILING WINDS OF THE GLOBE FOR JANUARY



BE FOR JULY.



Tanner & Shaw

ISOBARIC LINES AND PREVAILING WINDS OF THE GLOBE FOR JULY

TABLE SHOWING THE PRESSURE OF AQUEOUS VAPOUR IN INCHES OF MERCURY AT LATITUDE 45° FOR EACH DEGREE FAHRENHEIT FROM −30° TO 119°.

°	Inch.	°	Inch.	°	Inch.	°	Inch.	°	Inches.
−30	0·0099	0	0·0440	30	0·1665	60	0·5192	90	1·4128
−29	0·0105	1	0·0461	31	0·1738	61	0·5379	91	1·4578
−28	0·0111	2	0·0482	32	0·1815	62	0·5572	92	1·5040
−27	0·0117	3	0·0504	33	0·1888	63	0·5771	93	1·5514
−26	0·0123	4	0·0527	34	0·1964	64	0·5976	94	1·6001
−25	0·0130	5	0·0551	35	0·2043	65	0·6187	95	1·6502
−24	0·0137	6	0·0577	36	0·2125	66	0·6405	96	1·7017
−23	0·0144	7	0·0604	37	0·2210	67	0·6630	97	1·7546
−22	0·0152	8	0·0632	38	0·2297	68	0·6862	98	1·8088
−21	0·0160	9	0·0661	39	0·2388	69	0·7101	99	1·8646
−20	0·0168	10	0·0691	40	0·2482	70	0·7347	100	1·922
−19	0·0177	11	0·0723	41	0·2579	71	0·7601	101	1·980
−18	0·0186	12	0·0756	42	0·2679	72	0·7862	102	2·041
−17	0·0196	13	0·0790	43	0·2783	73	0·8131	103	2·103
−16	0·0206	14	0·0825	44	0·2890	74	0·8409	104	2·166
−15	0·0217	15	0·0862	45	0·3001	75	0·8695	105	2·231
−14	0·0228	16	0·0901	46	0·3116	76	0·8989	106	2·298
−13	0·0239	17	0·0942	47	0·3235	77	0·9292	107	2·366
−12	0·0251	18	0·0985	48	0·3358	78	0·9604	108	2·437
−11	0·0263	19	0·1030	49	0·3485	79	0·9925	109	2·509
−10	0·0276	20	0·1076	50	0·3616	80	1·0255	110	2·583
−9	0·0289	21	0·1124	51	0·3751	81	1·0595	111	2·659
−8	0·0303	22	0·1174	52	0·3891	82	1·0945	112	2·736
−7	0·0318	23	0·1226	53	0·4036	83	1·1305	113	2·817
−6	0·0333	24	0·1282	54	0·4186	84	1·1675	114	2·898
−5	0·0349	25	0·1339	55	0·4341	85	1·2056	115	2·982
−4	0·0366	26	0·1399	56	0·4501	86	1·2447	116	3·067
−3	0·0383	27	0·1461	57	0·4666	87	1·2850	117	3·156
−2	0·0401	28	0·1526	58	0·4836	88	1·3264	118	3·246
−1	0·0420	29	0·1594	59	0·5011	89	1·3690	119	3·338

Note by Mr. Cuthbert E. Peek.

As some travellers may not be able to take *with regularity* the series of observations, recommended in the preceding article, a less complete form is subjoined which will give very valuable information with regard to the country traversed, provided the few simple conditions are carefully fulfilled. The following instructions and a very convenient form of note-book are published by the Royal Meteorological Society, 22, Great George Street, Westminster.

Instructions to Observers at Climatological Stations.

Instruments Required.

Maximum Thermometer	divided	on the	stem and	verified.
Minimum	,,	,,	,,	,,
Dry Bulb	,,	,,	,,	,,
Wet Bulb	,,	,,	,,	,,
Rain Gauge				,,
Stevenson Thermometer Screen.				

Conditions to be Fulfilled.

Thermometer Screen.—To be placed over grass in a freely exposed situation.

Should never be in the shade, and must not be placed near any wall.

To be firmly mounted on four stout posts, at such a height that the bulbs of the dry and wet thermometers shall be four feet above the ground, and the door open to the north.

The thermometers to be placed as near the centre of the screen as possible. The most suitable arrangement is to mount the maximum and minimum thermometers on two small uprights in front of the dry and wet bulbs, in such a way that the scales of the latter can be seen above the former.

The maximum and minimum thermometers to be hung quite horizontally.

The screen must be painted *white*, and should be repainted during the spring of each year.

Wet Bulb Thermometer.—The bulb to be covered with a single piece of fine muslin; and have a conducting thread of three or four strands of darning cotton tied in the form of a noose round the neck of the bulb over the muslin, the ends of the thread passing into a water receptacle through a small orifice at the top, placed about three inches from the bulb.

Clean rain water alone to be employed.

The muslin and conducting thread to be soaked in boiling water prior to use, and to be changed at least once a month, and more frequently if there is any appearance of dirt or deposit.

When the temperature is below 32°, the bulb to be wetted about an hour *before* the time of observation, so that a coating of ice may be formed round the bulb.

Rain Gauge.—The rain gauge to be of copper, and have a funnel of five or eight inches diameter.

It is desirable that it have also a deep rim to retain snow.

The gauge to be placed in an open and well-exposed situation, free from trees, walls, and buildings, and firmly fixed so that it cannot be blown over.

The top of the funnel to be one foot above the ground, and quite level.

Observations.

The observations to be made once daily at 9 A.M. local time.

After the readings have been entered in the note-book, the instruments to be looked at again to see that no mistake has been made.

The maximum and minimum thermometers to be set; the former by holding the bulb downwards, and gently shaking the instrument, and the latter by holding the bulb upwards and allowing the index to flow to the end of the spirit.

The thermometers to be read to tenths of degrees. The reading of the maximum thermometer to be entered in the return to the *previous* day,

the readings of the other thermometers being entered to the day on which they are read.

Cloud.—The amount of cloud to be estimated according to the scale 0–10, 0, representing a cloudless sky, and 10 a completely covered or overcast sky.

The rainfall to be entered to the *previous* day.

When snow falls, that which is collected in the funnel to be melted by adding a known quantity of warm water, and entering the difference as rain. If the snow has drifted, a section of the snow should be obtained in a place where it has not drifted, by inverting the funnel and turning it round, and melting what is enclosed. It is also desirable to measure with a rule the depth of snow in several places where it has not drifted, and enter the amounts in the "Remarks."

Weather.—Notes on the general character of the weather during the day, and any phenomena such as fog, snow, thunder, &c., to be given in the "Remarks" column.

The following symbols to be used for brevity:

Rain	Thunderstorm	Dew
Snow	Thunder	Hoarfrost
Hail	Lightning	Silver Thaw
Soft Hail	Fog	Glazed Frost
Snow Drift	Solar Halo	
Ice Crystals	Lunar Halo	
Strong Wind	Lunar Corona	
Rainbow	Aurora	

NOTE.—The observations must be taken *punctually* at 9 A.M. local time, and with great care. As there must not be any break or omissions in the observations, it is desirable that there should be a well-trained deputy to take them in the absence of the regular observer.

Form.

Climatological Observations at 9 a.m. (Local Time) made at ______ during ____ _____18 . Height above Sea-level ______ feet

Date.	Thermometers.				Amount of Cloud.	Rain.	Remarks.
	Dry.	Wet.	Max.	Min.			
	°	°	°	°	0–10	In.	
1							
2							
&c.							
Sums							Maximum Temperature (corrected).....______on____
							Minimum Temperature (corrected) .....______on______
Means							Mean Temperature (Mean Max. and Min.)______
Corrections for Index Errors							Mean Range of Temperature ....
							Relative Humidity ....
Means Corrected.							No. of Rainy Days ...._______

TABLE OF

Dry Bulb Reading.	Difference between the Readings of													
	0·2°	0·4°	0·6°	0·8°	1·0°	1·2°	1·4°	1·6°	1·8°	2·0°	2·2°	2·4°	2·6°	2·8°
20°	93	86	80	74	68	63	59	55	51	47	44	41	37	34
22	94	88	82	76	70	65	60	56	53	50	47	44	41	38
24	94	88	83	78	73	69	65	61	57	53	50	47	44	42
26	95	90	85	80	76	72	68	64	61	57	54	51	48	45
28	96	92	88	84	80	76	72	69	66	63	60	57	54	52
30	96	93	90	87	84	81	78	75	72	70	67	64	62	60
32	97	94	91	89	87	84	82	80	78	76	73	71	69	67
34	97	95	93	91	89	87	85	83	81	80	78	76	74	72
36	98	96	94	93	91	89	87	86	84	82	80	79	77	76
38	98	96	94	93	91	89	87	86	85	83	81	80	78	77
40	98	97	95	94	92	90	88	87	86	84	82	81	79	78
42	98	97	95	94	92	90	88	87	86	84	83	81	80	78
44	98	97	95	94	92	90	88	87	86	84	83	82	81	79
46	99	97	95	94	92	91	89	88	87	85	84	82	81	79
48	99	97	95	94	92	91	89	88	87	85	84	82	81	80
50	99	97	96	94	93	92	90	89	88	86	85	83	82	80
52	99	97	96	94	93	92	90	89	88	86	85	83	82	81
54	99	97	96	94	93	92	90	89	88	86	85	83	82	81
56	99	97	96	94	93	92	90	89	88	87	86	84	83	82
58	99	97	96	94	93	92	90	89	88	87	86	85	84	83
60	99	97	96	94	93	92	91	90	89	88	86	85	84	83
62	99	98	96	95	94	93	91	90	89	88	86	85	84	83
64	99	98	96	95	94	93	91	90	89	88	86	85	84	83
66	99	98	96	95	94	93	91	90	89	88	87	86	85	84
68	99	98	96	95	94	93	92	91	90	89	87	86	85	84
70	99	98	96	95	94	93	92	91	90	89	87	86	85	84
72	99	98	96	95	94	93	92	91	90	89	87	86	85	84
74	99	98	96	95	94	93	92	91	90	89	88	87	86	85
76	99	98	97	96	95	93	92	91	90	89	88	87	86	85
78	99	98	97	96	95	94	93	92	91	90	89	88	87	86
80	99	98	97	96	95	94	93	92	91	90	89	88	87	86

RELATIVE HUMIDITY.

THE DRY AND WET BULB THERMOMETERS.															Dry Bulb Reading.
3·0°	3·2°	3·4°	3·6°	3·8°	4·0°	4·2°	4·4°	4·6°	4·8°	5·0°	5·2°	5·4°	5·6°	5·8°	°
32	29	27	25	23	21	19	18	17	16	15	14	13	12	11	20
36	33	31	29	27	25	23	21	19	18	17	15	14	13	12	22
39	36	34	32	30	29	27	25	23	21	19	18	17	16	15	24
43	41	39	37	35	33	31	29	27	26	25	23	21	20	19	26
50	48	46	44	42	40	38	36	34	33	32	30	29	27	26	28
58	55	53	51	49	47	45	44	42	40	39	37	36	35	33	30
65	63	61	60	58	56	54	53	51	50	48	47	45	44	42	32
71	69	67	65	63	62	60	59	57	56	55	53	52	51	50	34
74	72	71	69	68	66	64	63	61	60	59	58	57	55	54	36
76	74	73	71	70	69	67	66	64	63	62	61	60	58	57	38
76	75	74	72	71	70	68	67	65	64	63	62	61	60	59	40
77	76	75	73	72	70	69	68	66	65	64	63	62	61	60	42
78	77	76	74	73	72	71	70	68	67	65	64	63	62	61	44
78	77	76	74	73	72	71	70	68	67	66	65	64	63	62	46
79	78	77	75	74	73	72	71	69	68	67	66	65	64	63	48
79	78	77	75	74	73	72	71	70	69	68	66	65	64	63	50
80	79	78	76	75	74	73	72	71	70	69	67	66	65	64	52
80	79	78	77	76	75	73	72	71	70	69	68	67	65	65	54
81	80	79	77	76	75	74	73	72	71	70	69	68	67	66	56
82	81	80	78	77	76	75	74	73	72	71	70	69	68	67	58
82	81	80	78	77	76	75	74	73	72	71	70	69	68	67	60
82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	62
82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	64
83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	66
83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68
83	82	81	80	79	78	77	76	75	74	74	73	72	71	70	70
83	82	81	80	79	79	78	77	76	75	74	73	72	71	70	72
84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	74
84	83	82	81	80	80	79	78	77	76	75	74	73	72	71	76
85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	78
85	84	83	82	81	80	79	78	77	76	76	75	74	73	72	80

TABLE OF RELATIVE

Dry Bulb Reading.	DIFFERENCE BETWEEN THE READINGS OF														
	° 6·0	° 6·2	° 6·4	° 6·6	° 6·8	° 7·0	° 7·2	° 7·4	° 7·6	° 7·8	° 8·0	° 8·2	° 8·4	° 8·6	° 8·8
°															
20	10	9	8	7	6	6	6	5	5	5	5	..	..	..	..
22	11	10	9	9	8	8	7	7	6	6	5	5	5	5	4
24	14	13	12	11	10	10	9	9	8	8	7	7	6	6	6
26	18	17	16	15	14	14	13	12	11	10	10	9	9	8	8
28	25	24	23	21	20	19	18	17	16	15	15	14	14	13	13
30	32	31	30	29	28	28	27	26	25	24	23	22	21	20	19
32	41	39	38	37	36	35	34	33	32	31	30	29	29	28	27
34	49	47	46	45	44	43	41	40	39	38	37	36	36	35	34
36	53	52	51	49	48	47	46	45	44	43	42	41	40	39	39
38	56	55	54	52	51	50	49	48	47	46	45	44	43	42	42
40	58	57	56	54	53	52	51	50	49	48	47	46	45	44	44
42	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45
44	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46
46	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47
48	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
50	62	61	60	59	58	58	57	56	55	54	53	52	51	50	49
52	63	62	61	60	59	59	58	57	56	55	54	53	52	51	50
54	64	63	62	61	60	59	58	57	56	55	55	54	53	52	51
56	65	64	63	62	61	60	59	58	57	56	56	55	54	53	52
58	66	65	64	63	62	61	60	59	58	57	57	56	55	54	53
60	66	65	64	63	62	62	61	60	59	59	58	57	56	55	54
62	67	66	65	64	63	63	62	61	60	59	58	57	56	56	55
64	68	67	66	65	64	63	62	61	60	59	59	58	57	57	56
66	68	67	66	65	64	64	63	62	61	60	60	59	58	58	57
68	69	68	67	66	65	65	64	63	62	61	60	59	58	58	57
70	69	68	67	66	65	65	64	63	62	61	61	60	59	59	58
72	70	69	68	67	66	65	64	63	62	61	61	60	60	59	58
74	70	69	68	67	66	66	65	64	63	62	62	61	61	60	59
76	71	70	69	68	67	66	65	65	64	63	63	62	61	61	60
78	71	70	69	68	67	67	66	65	64	63	63	62	61	61	60
80	72	71	70	69	68	67	67	66	65	64	64	63	62	62	61

HUMIDITY.—*Continued.*

THE DRY AND WET BULB THERMOMETERS.

° 9·0	° 9·2	° 9·4	° 9·6	° 9·8	° 10·0	° 10·2	° 10·4	° 10·6	° 10·8	° 11·0	° 11·2	° 11·4	° 11·6	° 11·8	Dry Bulb Reading.
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	° 20
4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	22
5	5	5	5	5	4	..	..	..	..	..	..	..	..	..	24
7	7	6	6	6	5	5	5	5	5	4	..	..	..	..	26
12	12	11	10	10	9	9	8	8	7	7	7	6	6	6	28
18	17	16	15	15	14	14	13	13	12	12	12	11	11	10	30
27	26	25	24	23	23	22	21	20	20	19	19	18	17	17	32
33	33	32	31	30	30	29	28	27	27	26	26	25	24	24	34
38	37	36	35	34	34	33	32	31	31	30	30	29	28	28	36
41	40	39	38	37	36	35	34	33	33	32	32	31	30	30	38
43	42	41	40	39	38	37	36	35	35	34	34	33	32	32	40
44	43	42	41	40	40	39	38	37	36	36	35	34	33	32	42
46	45	44	43	42	41	41	40	39	39	38	37	36	35	34	44
47	46	45	44	43	43	42	41	40	39	39	38	37	36	35	46
48	47	46	45	44	44	43	42	41	40	40	39	38	37	36	48
49	48	47	46	45	45	44	43	42	41	41	40	40	39	39	50
50	49	48	47	46	46	45	44	44	43	43	42	41	40	40	52
51	50	49	48	47	47	46	45	45	44	44	43	42	41	41	54
52	51	50	49	48	48	47	46	46	45	45	44	43	42	42	56
53	52	51	50	49	49	48	47	47	46	46	45	45	44	44	58
54	53	52	51	50	50	49	48	47	46	46	45	45	44	44	60
55	54	53	52	51	51	50	49	48	47	47	46	46	45	45	62
55	55	54	53	52	52	51	50	49	48	48	47	47	46	46	64
56	55	54	53	52	52	51	51	50	49	49	48	48	47	47	66
56	56	55	54	53	53	52	52	51	50	50	49	48	47	47	68
57	57	56	55	54	54	53	52	51	50	50	49	49	48	48	70
58	57	56	55	54	54	53	53	52	51	51	50	50	49	49	72
59	58	57	56	55	55	54	54	53	52	52	51	50	49	49	74
59	59	58	57	56	56	55	54	53	52	52	51	51	50	50	76
60	59	58	57	56	56	55	55	54	53	53	52	52	51	51	78
60	60	59	58	57	57	56	55	54	53	53	52	52	51	51	80

TABLE OF RELATIVE

Dry Bulb Reading	Difference between the Readings of														
	12°·0	12°·2	12°·4	12°·6	12°·8	13°·0	13°·2	13°·4	13°·6	13°·8	14°·0	14°·2	14°·4	14°·6	14°·8
°															
20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
24	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
26	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
28	5	5	5	5	5	4	..	..	..	..	..	..	..	..	..
30	10	10	9	9	9	8	8	7	7	7	6	6	6	6	5
32	16	16	15	15	15	14	14	13	13	13	12	12	11	11	11
34	23	23	22	21	21	20	20	19	18	18	17	17	16	16	15
36	27	27	26	25	25	24	24	23	23	23	22	22	21	21	20
38	29	29	28	27	27	26	26	25	25	24	24	23	23	22	22
40	31	31	30	29	29	28	28	27	27	26	25	25	25	24	24
42	32	31	31	30	30	29	29	28	28	27	26	26	26	25	25
44	34	33	33	32	32	31	31	30	30	29	28	28	27	26	26
46	35	34	34	33	33	32	32	31	31	30	29	29	28	27	27
48	36	35	35	34	34	33	33	32	32	31	30	30	29	29	29
50	38	37	36	35	35	34	34	33	33	32	32	31	31	30	30
52	39	38	38	37	37	36	36	35	35	34	33	32	32	31	31
54	40	39	39	38	38	37	37	36	36	35	34	33	33	32	32
56	41	40	40	39	39	38	37	36	36	35	35	34	34	33	33
58	43	42	41	40	40	39	39	38	38	37	36	35	35	34	34
60	43	42	42	41	41	40	39	38	38	37	37	36	36	35	35
62	44	43	43	42	42	41	40	39	39	38	38	37	37	36	36
64	45	44	44	43	43	42	41	40	40	39	39	38	38	37	37
66	46	45	45	44	44	43	42	41	41	40	40	39	39	38	38
68	46	45	45	44	44	43	42	41	41	40	40	39	39	38	38
70	47	46	46	45	45	44	43	42	42	41	41	40	40	39	39
72	48	47	47	46	46	45	44	43	43	42	42	41	41	40	40
74	48	47	47	46	46	45	45	44	44	43	43	42	42	41	41
76	49	48	48	47	47	46	46	45	45	44	43	43	43	42	42
78	50	49	49	48	48	47	47	46	46	45	44	43	43	42	42
80	50	49	49	48	48	47	47	46	46	45	45	44	44	43	43

HUMIDITY.—*Continued.*

THE DRY AND WET BULB THERMOMETERS.

15·0°	15·2°	15·4°	15·6°	15·8°	16·0°	16·2°	16·4°	16·6°	16·8°	17·0°	17·2°	17·4°	17·6°	17·8°	18·0°	Dry Bulb Reading.
																°
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	22
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	24
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	26
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	28
5	5	5	5	4	4	..	..	..	..	..	..	..	..	..	..	30
10	10	10	10	9	9	9	8	8	8	7	7	7	7	6	6	32
15	15	14	14	14	13	13	13	12	12	12	11	11	11	10	10	34
20	19	19	18	18	17	17	16	16	15	15	14	14	14	13	13	36
21	21	20	20	20	19	19	18	18	17	17	16	16	16	15	15	38
23	23	22	22	22	21	21	20	20	19	19	18	18	18	17	17	40
24	24	23	23	23	22	22	21	21	20	20	19	19	19	18	18	42
25	25	24	24	24	23	23	22	22	21	21	20	20	20	19	19	44
26	26	25	25	25	24	24	23	23	22	21	21	21	21	20	20	46
28	27	27	26	26	25	24	23	23	22	22	22	21	21	20	20	48
29	28	28	27	27	26	26	25	25	24	24	23	22	22	21	21	50
30	29	29	28	28	27	27	26	26	25	25	24	24	24	23	23	52
31	30	30	29	29	28	28	27	27	26	26	25	25	25	24	24	54
33	32	32	31	31	30	29	29	28	28	27	27	26	26	25	25	56
34	33	33	32	32	31	31	30	30	29	29	28	28	28	27	27	58
35	34	34	33	33	32	32	31	31	30	30	29	29	28	28	27	60
35	35	34	34	33	33	33	32	32	31	31	30	30	29	29	28	62
36	36	35	35	34	34	33	32	32	31	31	30	30	29	29	29	64
37	36	36	35	35	34	34	33	33	32	32	32	31	31	30	30	66
38	37	37	36	36	35	35	34	34	33	33	33	32	32	31	31	68
38	38	37	37	36	36	35	35	35	34	34	33	33	32	32	31	70
39	39	38	38	37	37	36	36	35	35	34	34	34	33	33	32	72
40	40	39	39	38	38	37	37	36	36	35	35	35	34	34	33	74
41	40	40	39	39	38	38	37	37	37	36	36	36	35	35	34	76
41	41	40	40	39	39	39	38	38	37	37	36	36	35	35	34	78
42	41	41	40	40	39	39	38	38	37	37	36	36	35	35	35	80

In the Table is given the relative humidity for every 2° of temperature from 20° to 80°, and for every two-tenths of a degree of difference between the dry and wet-bulb readings from 0°·2 to 18°·0.

To use the Table: Look in the column on the left or right for the nearest degree to the dry-bulb reading; then carry the eye horizontally along until the column is reached corresponding to the difference between the readings of the dry and wet-bulb thermometers, when the relative humidity will be found. Intermediate readings can be interpolated in the usual way.

Example: Dry-bulb 58°·5, wet-bulb 52°·7, the difference is 5°·8. Having found 58° in the column on the left or right, run the eye along this line until the column under 5°·8 is reached when the relative humidity will be found, viz., 67.

Hints to Meteorological Observers in Tropical Africa, with Instructions for taking Observations.

Prepared by a Committee of the British Association for the Advancement of Science, 1891. E. G. Ravenstein, F.R.G.S., *Chairman*; Baldwin Latham, C.E., F.G.S.; G. J. Symons, F.R.S.; H. R. Mill, D.SC., *Secretary*.

The Committee appointed by the British Association are prepared to supply a few competent and approved observers in Tropical Africa with the following instruments:—

1. A Fortin's Barometer.
2. A Dry Bulb Thermometer.
3. A Wet Bulb ,,
4. A Maximum ,,
5. A Minimum ,,
6. A Rain Gauge.

The Thermometers are placed within a cage of galvanised iron, ready for suspension under shelter.

The corrections to be applied to the readings of the instruments furnished by the Committee have been ascertained, and will be forwarded to each observer. Observations, however, should be entered in the

Register as actually recorded by the instrument, and without applying any of these corrections.

Observers making use of instruments not supplied by the Committee, are earnestly requested to furnish a description of them (maker's name and number), with such notes on their errors as may be in their possession.

Every opportunity for comparing the instruments at a station with other instruments in the possession of travellers and others should be availed of.

The Committee will be happy to make careful abstracts of any Meteorological Journals from Africa which may be intrusted to them.

They will also forward (gratis) copies of these 'Hints,' and of their 'Register,' to any observer who may apply for them.

Descriptions of certain instruments, not as a rule supplied by the Committee, will be found in 'Hints to Meteorological Observers,' prepared under the direction of the Council of Royal Meteorological Society by W. Marriott. London (Stanford), 1892. Price 1s. These instruments are the Kew barometer, Philips's maximum thermometer, black and bright bulb thermometers *in vacuo*, grass minimum thermometer, Symons's earth thermometer, percolation gauge, Robinson's anemometer, and the sunshine recorder.

Notes on Mounting the Instruments.

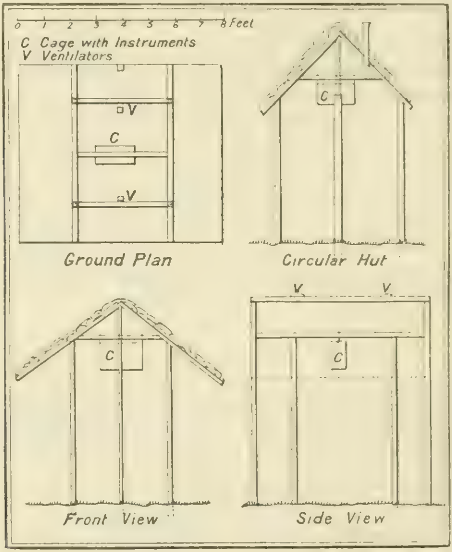
Fortin's Barometer should be mounted in a room not subject to sudden or great changes of temperature. Care should be taken to suspend the instrument vertically, to place it in a good light and not near a fireplace, or where it is exposed to the sun.

It is to be fixed at such a height that the observer can read the vernier comfortably when standing upright. The height of the cistern above the ground should be noted in the register.

Barometers should be *carefully* handled. Before moving one first turn the screw below the cistern until the mercury fills the tube, then turn the barometer carefully over, and carry it with the cistern end upwards.

Thermometers.—The thermometers are placed within an iron cage, which should at all times be kept locked, so as to prevent interference with the instruments. This cage is suspended under a thatched shelter, which should be situated in an open spot at some distance from buildings, must be well

ventilated, and guard the instruments from being exposed to sunshine or rain, or to radiation from the ground. A simple hut, made of materials available on the spot, would answer this purpose. Such a hut is shown in the accompanying drawing. A gabled roof with broad eaves, the ridge of which runs from north to south, is fixed upon four posts, standing four feet apart. Two additional posts may be introduced to support the ends of the ridge beam. The roof, at each end, projects about 18 inches. In



it are two ventilating holes. The tops of the posts are connected by bars or rails, and on a cross-bar is suspended the cage with the instruments. These will then be at a height of six feet above the ground. The gable ends may be permanently covered in with mats or louvre work, not interfering with the free circulation of the air, or the hut may be circular.

The roof may be covered with palm-fronds, grass, or any other material

locally used by the natives as building material. The floor should not be bare, but covered with grass or low shrubs.

Care should be taken to fix the cage firmly, so that the maximum and minimum thermometer may not be disturbed by vibration.

Rain Gauge.—It should be firmly fixed in the ground with the top of the rim one foot, or if on bare soil one foot three inches, above it, and perfectly horizontal.

Wind Vane.—The vane should be placed where it is freely exposed to the action of the wind, and not interfered with by local conditions. It should be higher than the trees or buildings near it, and under any circumstances about 25 feet above the ground. Its north point is readily obtained by means of a compass, applying, as a matter of course, the local variation.

Instructions for Taking the Observations.

Hours of Observation.—At stations of the second order the instruments are to be read at 7 a.m., 2 p.m., and 9 p.m., with the exception of the maximum and minimum thermometers and the rain gauge, which are only read at 7 a.m.

At climatological stations the observations are made only once daily, viz., at 9 a.m.

Register.—All the original observations should be written down at the time in a properly ruled note-book, which should be preserved for reference in case any question should arise about them afterwards.

In entering the observations in the register supplied by the Committee it is absolutely essential that they be correctly copied from the original note-book, and carefully checked.

The first Monthly Register should be accompanied by a description of the station and of its environs, as also an account of the situation, &c., of the instruments. Any subsequent changes in the latter should be duly noted.

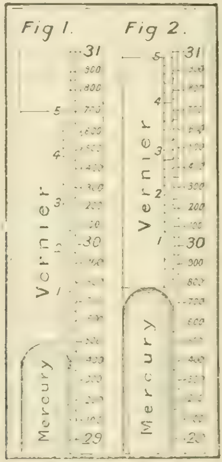
Fortin's Barometer.—1. Note (to nearest degree) the reading of attached thermometer.

2. Bring surface of mercury in the cistern into contact with the ivory point which forms the extremity of the scale by turning the screw at the bottom of the cistern. The ivory point and its reflected image in

the mercury should appear just to touch each other and form a double cone.

3. Adjust the vernier scale so that its two lower edges shall form a tangent to the *convex* surface of the mercury. The front and back edges of the vernier, the *top* of the mercury, and the eye of the observer are then in the same straight line.

4. Take the reading, and *enter the observation as read* without either correcting it to freezing-point or reducing it to the sea-level.



The scale fixed to the barometer is divided into inches, tenths, and half-tenths, so that each division on this scale is equal to 0·050 inch.

The small movable scale or vernier attached to the instrument enables the observer to take more accurate readings; it is moved by a rack and pinion.

Twenty-four spaces on the fixed scale correspond to twenty-five spaces on the vernier; hence each space on the fixed scale is larger than a space on the vernier by the twenty-fifth part of 0·050 inch, which is 0·002. Every long line on the vernier (marked 1, 2, 3, 4, and 5) thus corresponds to 0·010 inch.

If the lower edge of the vernier coincides with a line on the fixed scale, and the upper edge with the twenty-fourth division of the latter higher up, the reading is at once supplied by the fixed scale as in Fig. 1, where it is 29·500 inches.

If this coincidence does not take place, then read off the division on the fixed scale, above which the lower edge of the vernier stands. In Fig. 2 this is 29·750 inches. Next look along the vernier until one of its lines is found to coincide with a line on the fixed scale. In Fig. 2 this will be found to be the case with the second line above the figure "2." The reading of the barometer is therefore:—

On fixed scale	29·750
On vernier (12 × ·002)	·024
Correct reading	29·774

Should two lines on the vernier be in equally near agreement with two on the fixed scale, then the intermediate value should be adopted.

5. Lower the mercury in the cistern by turning the screw at the bottom until the surface is well below the ivory point; this is done to prevent the collection of impurities.

Dry Bulb and Wet Bulb Thermometers.—Readings should be entered without applying any corrections for the errors of the instruments. They should be stated in degrees and tenths of degrees.

Five, or preferably ten, minutes before reading the Dry Bulb Thermometer in damp weather it is to be wiped dry.

The Wet Bulb Thermometer requires special attention. The bulb should be covered with a piece of the thinnest muslin. Eight threads of darning cotton, in the form of a noose, should be *loosely* tied round the neck of the bulb, and led through a small hole in the cover of the water receptacle or cup. Take care to have this cup at all times filled with clean rain or filtered water.

The muslin and the conducting threads should be washed in boiling water prior to use, and changed at least once a month, or whenever there is any appearance of dirt upon them.

When the temperature sinks below freezing-point, wet the bulb with a camel hair brush about an hour before use; this will produce a thin coating of ice.

After a frost the water in the receptacle should be thawed, and the muslin and conductor washed, to restore proper action.

Maximum Thermometer (Negretti & Zambra's).—1. See that the end of the column nearest the bulb has not run away from it through vibration or otherwise. If it has the thermometer should be tilted *very* gently until the detached column comes in contact with the contraction in the tube.

2. Read at 7 a.m. or 9 a.m. by noting the point at which the end of the column of mercury is lying. *Enter to previous day.*

3. Set, by holding the thermometer bulb downwards, and shaking it until the mercurial column becomes continuous throughout. The end of the mercury should then indicate the same temperature as the Dry Bulb Thermometer.

Minimum Thermometer (Rutherford's).—1. Read at 7 a.m. or 9 a.m. by noting position of the end of the index *furthest* from the bulb. Enter to the day on which read.

2. Set, by raising the bulb and allowing the index to slide to the end of the column of spirit. When set, the end of the index furthest from the bulb should indicate nearly the same temperature as the dry bulb.

Rain Gauge.—The gauge should be examined daily at 7 a.m. or at 9 a.m. During exceptionally heavy rains it may be necessary to measure the contents of the gauge at more frequent intervals, but the total results should in all cases be inserted in the register under the hours named.

The rain measured at 7 a.m. or 9 a.m. should be entered as having fallen the previous day.

The measurement is effected by pouring the contents of the gauge (bottle or can) into a glass measure, each division of which represents 0·01 in. The reading to be taken midway between the two apparent surfaces of the water.

If hail or snow should be collected in the funnel, it is to be melted and measured as rain. This is done by adding to the hail or snow a measured quantity of hot water, and by afterwards deducting the quantity so added from the total measurement.

Wind.—Note the *direction* from which the wind blows from the indications of a freely-moving vane, or by observing the drift of smoke by means of a magnetic compass, applying the correction for variation.

The *Force of the Wind* is to be noted according to Beaufort's scale, as follows:—

	Corresponding Velocity in Miles per Hour.
0. Calm	0— 5
1. Light Air	6—10
2. Light Breeze	11—15
3. Gentle "	16—20
4. Moderate "	21—25
5. Fresh "	26—30
6. Strong "	31—36
7. Moderate Gale	37—44
8. Fresh "	45—52
9. Strong "	53—60
10. Whole "	61—69
11. Storm	70—80
12. Hurricane	81 and upwards.

Clouds.—The *proportion* of the sky covered with cloud is to be estimated, the scale adopted being 0—10, 0 representing a perfectly cloudless sky, and 10 showing that the *whole* sky is clouded.

The *forms* of clouds should be described as defined by Howard, as follows:—

Cirrus:—Parallel, wavey, or diverging fibres.
Cirro-cumulus:—A fleecy cloud.
Cirro-stratus:—A thin veil of feathery or streaky cloud.
Cumulus:—A cloud of a convex or well-rounded shape.
Cumulo-Stratus:—A blending of Cirro-Stratus with Cumulus.
Stratus:—Clouds in continuous horizontal sheets.
Nimbus or rain cloud.

Under *motion* enter the direction whence the cloud is moving.

Weather.—Note any phenomena which may have occurred since the last observation.

Term-Days.—On the 1st, 11th, and 21st of each month hourly or two-hourly observations should, if possible, be taken, those of the 21st being the most important. This applies more especially to the barometer and its attached thermometer, and to the dry and wet bulb thermometers.

Additional Observations.—If the station is favourably situated for measuring the height of a lake-level or ascertaining the flooding of a river, this should be done. These observations should be made regularly daily, but if this is impracticable, once a week is much better than none. The water-gauge should be divided into inches and tenths. The manner of fixing it must depend entirely upon local circumstances: its zero should coincide with the lowest level of the water, but in practice it will generally be necessary to accept an arbitrary zero, and to indicate all readings below it by a minus sign. It is desirable that the zero of the gauge should be referred to a bench mark cut in the face of a rock, or failing that, in the trunk of a tree.

Well-measurements may prove of interest. Measure the distance from the mouth of the well to the surface of the water in it, and *not* the depth of the well. At stations on the sea-shore, on lakes or rivers, the temperature of the water may likewise be recorded.

Note by ROBERT H. SCOTT, F.R.S.

Extract from the Report of the International Meteorological Conference held at Munich, September, 1891.

1. It should be stated what kind of instruments had been used for the observations, their corrections should be given, if known; as well as details as to the method of exposure. The height of the barometer above sea-level should be given as accurately as possible.

2. Precise information as to the methods employed in the calculation of means (the hours of observation and the formulæ used for reductions) should always be given.

It is further desirable to give the means for the separate hours of observation (for temperature, humidity, and atmospheric pressure), to facilitate the reduction to true means, which might be undertaken subsequently.

3. In publishing means for several years, it is very desirable to give the separate means for periods of five years each (lustra) (commencing with the first year of each pentade:—1881–5, 1886–90, &c.), in accordance with the resolution of the Congress of Vienna. In this way it would be

possible to obtain with the greatest facility simultaneous and corresponding mean values which are indispensable for any serious investigations on the distribution of meteorological elements, especially temperature, atmospheric pressure, and rainfall.

List of Meteorological Stations and Organisations, 1893; Furnished by the Meteorological Office.

Asia.

Asia Minor.

Beirút	R. H. West, Esq., M.A., Superintendent, Lee Observatory, Syrian Protestant College.
Cyprus	The Chief Medical Officer, Larnaka.

China.

Zi-ka-wei	Rev. F. S. Chevalier, S.J., Observatoire Magnétique et Météorologique, Zi-ka-wei, près Shanghai.
Hong-Kong	Dr. W. Doberck, Government Astronomer, Observatory.

Japan.

Tokyo	M. Kobayashi, Director, Imperial Meteorological Observatory, Tokyo.

India.

Calcutta	J. Eliot, Esq., M.A., Meteorological Reporter to the Government of India.

Africa.

West Africa.

Lagos	The Colonial Surgeon, Colonial Hospital.

Algeria.

Algiers	M. le Directeur du Service Météorologique.

South Africa.

Cape Town	W. E. Fry, Esq., Secretary, Meteorological Commission.
Walfisch Bay	Dr. Stapff.

East Africa.

Mauritius	C. Meldrum, Esq., LL.D , F.R.S., Secretary, Meteorological Society.

North Africa.

Cairo	Administration des Services Sanitaires et d'Hygiène Publique.

Madagascar.

Mojanga	S. C. Knott, Vice-Consul.
Antananarivo	Royal Observatory, M. Colin, S.J.

AMERICA.

North America.

Washington	Weather Bureau.
Labrador (Six stations.)	German Missionaries.

Canada.

Toronto	C. Carpmael, Esq., M.A., Meteorological Office.

South America.

Córdoba	Sr. W. G. Davis, Oficina Meteorologica Argentina.
Porto Alegre	Dr. G. Alves d'Azambuja, Porto Alegre, South Brazil.
Georgetown	G. S. Jenman, Esq., Government Botanist's Office, Georgetown, Demerara.
Rio de Janeiro	Capt. Adolph Pinheiro, Bureau Hydrographique.

Central America, &c.

Havana	Padre B. Viñes, S.J., Director, R. Colegio de Belen, Havana, Cuba.
Mexico	The Director, Observatorio Central del Palacio Nacional.
Tacubaya	Sr. Ángel Anguiano, Observatorio Astronómico Nacional.
Tobago	J. P. Tulloch, Esq., M.D., Colonial Surgeon.
Trinidad	J. H. Hart, Esq., Superintendent, Botanic Gardens.
Belize	St. Joseph's College.
Costa Rica	Meteorological Institute.

AUSTRALASIA.

New South Wales.

Sydney	H. C. Russell, Esq., F.R.S., Observatory.

Queensland.

Brisbane	C. L. Wragge, Esq., F.R.A.S., Government Meteorologist.

South Australia.

Adelaide	Sir C. Todd, K.C.M.G., F.R.S., Superintendent of Telegraphs.

Tasmania.
Hobart .. .. .. Hon. Secretary, Royal Society of Tasmania.

Victoria.
Melbourne .. .. R. J. Ellery, Esq., F.R.S., Observatory.

West Australia.
Perth .. .. M. A. C. Fraser, Esq., Meteorological Reporter.

New Zealand.
Wellington .. .. Sir J. Hector, C.M.G., M.D., F.R.S., Colonial Museum.

Java.
Batavia .. .. .. Dr. J. P. van der Stok, Director, Observatory.

Philippine Islands.
Manila .. .. .. The Director, Meteorological Observatory.
Sandwich Islands .. H. Cobb-Adams, Kaneohe (Oahu).
Fiji .. .. J. D. W. Vaughan, Suva.
Samoa .. .. .. Dr. Frank, Apia.

This list, of course, is very far from exhaustive. The Russian Government has established a great number of stations throughout the Empire. The number of places where observations are regularly taken is yearly increasing, and the traveller will do well to inquire where such stations exist in the neighbourhood of his explorations.—EDITORS.

VII.

GEOLOGY.

By W. T. Blanford, F.R.S.

A traveller who has not devoted some time to studying geology in the field must not be surprised or disappointed if the rocks of any country which he may happen to traverse appear to him a hopeless puzzle. If he desires to investigate the geological structure of an unknown region, he should previously devote some time to mastering, with the aid of a good geological map and description, the details of a well-known tract.

Under the term "Geological Observations," two very distinct types of inquiry are commonly confounded. The first of these, to which the name of Geological Investigation ought properly to be restricted, consists in an examination of the rocks of a country as a whole, so as to enable a geological map, or, at all events, geological sections, to be constructed. This demands a knowledge of rocks (petrology), some acquaintance with the details of geological surveying, and, usually, with the elements of palæontology—a science that, in its turn, requires a preliminary study of biology, and especially of zoology. Despite all these hard terms, any intending traveller who has a taste for geology—if he has none he had better not waste time upon the subject—will find that a few months' study in any good museum, a course of geological lectures, and, above all, a few days in the field with a good geologist, will start him very fairly equipped with the great requisite to all successful scientific investigation, a knowledge of how to observe, and what to observe

The term "Geological Observations" is, however, often, but incorrectly, used in a second sense, which implies a restriction of the observations to the useful minerals found in any country, or to what is termed economic geology. Here also a preliminary knowledge of the elements of geological science will be found very useful, and will frequently enable the traveller

to form much more trustworthy conclusions as to the nature and value of mineral deposits than he could without such a guide. But the essential point is to recognise a valuable mineral when seen, and for this some knowledge of mineralogy is requisite.

Outfit.—The essential articles of a geologist's outfit are neither numerous nor cumbrous. A very large proportion of the known geology of the world has been made out with no more elaborate appliances than a hammer, a pocket compass, with a small index to serve as a clinometer, a pocket lens, a note-book and a pencil. No scientific observer has to depend more on his own knowledge and faculty for observation, and less on instrumental appliances, than a geologist.

The best hammer for general purposes should weigh from 1 to 2 lbs. and should have a square flat end, and a straight cutting end—the latter may be horizontal or vertical, according to fancy. The ends should be of steel, not too highly tempered. The hole for the handle should be as large as possible (with a small hole the handles are so weak as to be liable to break), and the handle should be secured in the hole by a wooden wedge, and an iron one driven into and across the wooden one. It is advisable to take a few spare ash handles. Cut a foot-measure in notches on the handle—this is very useful for measuring thickness of beds, &c. It is as well to have more than one hammer in case of loss, and if fossil-collecting is anticipated, at least one heavy hammer, with one end fashioned to serve as a pick, three or four cold chisels of various sizes, and a short crow-bar will be found useful. Excellent geological hammers are those used by the Irish Geological Survey, and made by Kennan, of Dublin. In London, hammers, chisels, &c., may be procured of J. R. Gregory, 88, Charlotte Street, Fitzroy Square; or of Messrs. Buck, 242, Tottenham Court Road.

A very good pocket compass, the shape and size of a watch, with a clinometer arm, is made by Troughton and Simms, 138, Fleet Street. The use of the clinometer is for measuring the angle of dip in rocks. The elaborate instruments used for mining purposes are unnecessary to the geologist. If more accuracy of measurement is required than is afforded by looking at a bed, a section, or a hill-side, and holding the straight-edge attached to the compass parallel to the dip, and if a surface can be found that affords the exact inclination, it is usually practicable, by means of a note-book laid on the rock surface, to obtain a plane sufficiently close to that at which the beds dip to enable the angle to be

determined with a very short straight-edge. As a rule, except with very low angles of dip, the variation in the inclination of the rocks themselves exceeds the limits of error of the instrument. A little care, however, is necessary in taking dips; for the apparent dip seen in a section, such as is often exposed in a cliff, may differ widely from the true dip, which will only be shown if the section runs at right angles to the strike of the beds. Dips seen on the sides of hills at a distance are but rarely correct for the same reason.

A prismatic compass and an aneroid are frequently of great service: the former to determine the position on the map, if one exists, and to aid in making a rough map, if there is none; and the latter to estimate roughly the heights on the road travelled, especially in mountainous countries, and also to measure the thickness of horizontal beds. Both form a part of the outfit of most modern travellers. A good aneroid gives sufficiently accurate determinations of height for a rough but adequate geological section across any country, if the distances are known.

Collections.—Geological specimens require little more than paper and boxes for packing. Occasionally fossils or minerals are fragile, and need tow or grass to protect them from injury; but there is no risk from the animal and vegetable enemies of zoological or botanical collections. The only important point to be borne in mind is that *every specimen should be labelled on the spot*, or, at all events, in the course of the day on which it is collected. Strong paper is best for labels, and these should not be put up in contact with the rock-fragments themselves, or they will be worn by sharp edges and become illegible, if not rubbed to fragments. Always wrap each specimen in paper, or some substitute, then add the label, and then an outer covering. The label,* if nothing else is written, should always record the locality distinctly written.

* Travellers in tropical countries will do wisely to poison all their labels before using them, to preserve them from attacks of insects and mites. Washing with a very weak solution of corrosive sublimate is an efficient plan. A large number of labels, with the collector's name printed on them, may be taken, and if made of strong thin paper they will not occupy much space. Bank-note paper is well adapted for the purpose. Any writing should be, if possible, in ink; if not, a very hard black pencil should be used.

A collection of rock specimens may show what kinds of rock occur in a country, but the information afforded is very meagre, and, in general, of very small value. Such collections, indeed, unless made by a geologist, and accompanied by notes, are scarcely worth the carriage. If such specimens are taken, care should be used to select them from the rocks in place, not from loose blocks that may have been transported from a distance, and no fragments of spar or crystals should be collected merely because they are pretty.

In taking specimens of useful minerals, such as coal or metallic ores, the traveller should always endeavour to procure them himself from the place of occurrence, and if such are brought to him by natives, he should, if practicable, visit the locality whence the samples were procured. The value of all useful minerals depends both on quality and quantity; the former can to some extent be ascertained from a sample, but the amount available can only be estimated after a visit to the locality. Most metallic ores occur in veins or lodes. These were originally cracks in the rock, and have been irregularly filled with minerals, different from those in the neighbourhood. It is, however, very difficult, and often impossible, to estimate from surface examination whether the quantity of ore occurring in veins is likely to prove large; some idea may possibly be obtained if underground workings exist. Many of the ores of iron, some of those of other metals, and all coal and salt occur in beds, and here it is important to see what is the thickness, and to ascertain whether the mineral is equally pure throughout. Iron ores occur in most countries, and unless very pure and within easy reach of water-carriage, are not likely to be worth transport. The value of salt also depends on facilities for carriage. Coal, however, may be of value anywhere; but it is improbable that seams of less thickness than four or five feet can be of much use, except in countries where there is a skilled mining population and a considerable demand for the mineral. It does not follow because much thinner seams are sufficiently valuable to be worked in Western Europe that they would pay for extraction in a country where the mechanical arts are less advanced. Still the occurrence of thin seams is worthy of record, as thicker deposits may exist in the neighbourhood. It must not be inferred, however, that a seam of small thickness at the surface will become thicker below. The reverse is equally probable.

A blow-pipe is extremely useful for ascertaining the nature of ores, and

for determining minerals generally, and a small blow-pipe case might be added to a traveller's kit, if he thinks it probable that he may meet with minerals in any quantity. But in general they are not to be found in such profusion as to render it difficult to carry away specimens sufficient for determination at leisure. A blow-pipe, too, is of no use to any one unacquainted with the method of employing it, though this is easy to acquire.*

To form a rough idea of the value of iron ore, see whether it is heavy; to form some notion of the quality of coal, pile up a heap and set fire to it. If it does not burn freely, the prospects of the coal being useful are small. It may be anthracitic, and very valuable with proper appliances; but anthracite is not of the same general utility as bituminous coal. Good coal should burn freely, with more or less flame, and should leave but little ash, and it is preferable that the ash should be white, not red, as the latter colour is often due to the presence of pyrites, a deleterious ingredient.

Gold and gems have, as is well known, been procured in considerable quantities from the sands of rivers and alluvial deposits. The deposits known to the natives of any country are often of small value, and the rude methods of washing prevalent in so many lands suffice to afford a fair idea of the wealth or poverty of the sand washed. Gold and, wherever it is found, platinum occur in grains and nuggets, easily recognised by their colour and by their being malleable; but gems, such as diamond, ruby, sapphire, are not so easy to tell from less valuable minerals. They may be recognised by their crystalline form and hardness. A diamond is usually found in some modification of an octohedron, and the crystalline facets are often curved; rubies and sapphires are really differently coloured varieties of the same mineral, and occur, when crystalline, in six-sided pyramids or some modification. A diamond is the hardest of known substances; nothing will scratch it, and it will scratch all other minerals. Sapphire will scratch everything except diamond.

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* There are plenty of good works on the use of the blow-pipe. The best are by Plattner and Scheerer, of both of which English translations have been published. Of Von Kobell's tables for the determination of minerals, several translations have appeared.

In collecting fossils, it is useless to take many specimens of one kind unless carriage is exceptionally plentiful. Two or three good examples of each kind are usually sufficient, but as many kinds as possible should be collected. Great care is necessary that all the specimens from one bed be kept distinct from those from another stratum, even if the bed be thin and the fossils in the two beds chiefly the same species. If there is a series of beds, one above the other, all containing fossils, measure the thickness roughly, draw a sketch-section in your note-book, apply letters or numbers to each bed in succession on the sketch, and label the fossils from that bed with the same letter or number.

Remains of Vertebrata, especially of mammals, birds and reptiles, are of great interest; but it is useless to collect fragments of bones without terminations. Skulls are much more important than other bones, and even single teeth are well worth collecting. After skulls, vertebræ are the most useful parts of the skeleton, then the limb bones. If complete skeletons are found, they are usually well worth some trouble in transporting. If fossil bones are found abundantly in any locality, and the traveller has no sufficient means of transport, he will do well to carry away a few skulls, or even teeth, and carefully note the locality for the benefit of future geologists and explorers. The soil of limestone caverns, and especially the more or less consolidated loam, rubble, clay, or sand beneath the flooring of stalagmite, if it can be examined, should always be searched for bones, and also for indications of man or his works.

The foregoing remarks are intended for all travellers, especially for those who have paid little or no attention to geology. It would be far beyond the object of the present notes to attempt to give instruction in the methods of geological observation; all who wish to know more fully what questions are especially worthy of attention, should consult the article on Geology by the late Dr. Charles Darwin and Professor J. Phillips in the 'Admiralty Manual of Scientific Enquiry.' But a few hints may be usefully added here for those who have already some knowledge of geology, who do not require to have such terms as dip, strike, fault, or denudation explained to them, and who are sufficiently conversant with geological phenomena to be able to distinguish sedimentary from volcanic, and metamorphic from unaltered rocks, and to recognise granite, gneiss, schist, basalt, trachyte, slate, limestone, sandstone, shale, &c., in the field. Assuming then that a traveller with some knowledge of field geology is

making a journey through a tract of the earth's surface, the geology of which is unknown, what will be the best method of procedure and the principal points to which he should direct his attention?

On the whole, the most useful record of a journey, whether intended for publication or merely as a memorandum, is a sketch geological map of the route followed, with the dips and strikes of the rocks and approximate boundaries to the formations, supplemented by notes and sketch-sections. Where, as is commonly the case in mountain-chains, and frequently in less elevated portions of the country, the rocks are much disturbed, and especially if the number of systems exposed is large and the changes frequent, no traveller can expect to do more than gain a very rough and general idea of the succession of beds in detail, and of the structure; but by making excursions in various directions, whenever a halt is practicable, by searching for fossils as a guide to the age and for the identification of beds with each other, and by carefully noting the general dip and strike of the more conspicuous beds, it is often possible, especially if an opportunity occurs of retracing the road followed, or of traversing a parallel route, to make out the structure of a country that at first appears hopelessly intricate. Dense forest is perhaps the worst obstacle to geological exploration; snow is another, though not quite so serious a disadvantage. It is always a good plan to climb commanding peaks; the general direction of beds, obscure from the lower ground, not unfrequently becomes much clearer when they are seen from above.

In level and undulating regions, on the other hand, it frequently happens that enormous tracts of country are occupied by the same formation, and if the rocks are soft, and especially if they are horizontal, or nearly so, little, if any, rock is to be seen in place. In this case water-courses should be searched for sections, and the pebbles found in the stream-beds examined, care being taken not to mistake transported pebbles derived from overlying alluvium or drift for fragments of the underlying rock. Where the same formation prevails over large tracts, it is usually easy, by examining the stones brought down by a stream, to learn whether any other beds occur. It is astonishing how even a small outcrop of hard rock at a remote spot in the area drained by a stream will almost always yield a few fragments that can be detected by walking two or three hundred yards up the stream-bed and carefully examining the pebbles.

Not unfrequently different rocks support different vegetation, and by noting the forms that are peculiar, the constitution of hills at a considerable distance may be recognised. Thus some kinds of rock will be found to support evergreen, others deciduous trees, others grass, whilst a fourth kind may be distinguished by the poverty or want of vegetation. It is not well to trust too much to such indications, but they may show which hills require examination and which do not. The form assumed by the outcrop of some hard beds is often characteristic, and may be recognised at a considerable distance.

One most important fact should never be forgotten; mineral character, whether of sedimentary or volcanic rocks, is absolutely worthless as a guide to the age of beds occurring in distant countries. The traveller should never be led to suppose, because a formation, whether sedimentary or volcanic, in a remote part of the world, is mineralogically and structurally identical with another in Europe, or some country of which the geology is well known, that the two are of contemporaneous origin. The blunders that have been made from want of knowledge of this important caution are innumerable.

There are a few points of geological interest well worthy of the investigation of those who traverse unexplored, or partially explored, tracts of the earth's surface. Amongst these are the following:—

Mountain-Chains.—Few, if any, geologists now believe that mountains were simply thrust up from below; all admit that, at least in the majority of cases, where great crumbling of the strata has taken place, there has been lateral movement of the earth's crust. But the causes, extent and date, of the lateral movements are still, to a great extent, matters of conjecture, and every additional series of observations bearing on the question is of importance. There are many mountain-chains of which very little is yet known. In each case good sections are required, drawn as nearly to scale as practicable, through the range from side to side, and including the rocks on the flanks. The nature and distribution of all volcanic and crystalline rocks, both in the range and throughout the neighbouring areas, are especially noteworthy, and also the relations of the later beds, if any, on the flanks of the mountains, to those constituting the range itself, the derivation of the materials of the former from the latter, and the relative amount of disturbance shown by the two, and by the different members of each.

Volcanoes and Volcanic Rocks.—It is almost needless to say that any additional information on the distribution of volcanic vents, recent or extinct, is of interest. In the case of extinct vents, the geological date of the last eruptions should be ascertained if practicable. This may sometimes be determined by finding organic remains or sedimentary beds of known age interstratified with the ashes or lava-streams near the base of the volcano.

Additional observations are needed as to the extent and age of those enormous masses of stratified volcanic rocks that occur in some parts of the earth, as in the western part of the Indian Peninsula, North-eastern Africa, the Western States of North America, and on a smaller scale in parts of Europe.

Coasts.—The subject of the erosion of coasts is now fairly understood, and there is no doubt that the importance of this form of denudation was greatly overrated by many geological writers, who took their ideas of geological denudation generally from the phenomena observed in the islands, and on some of the coasts of Western Europe. Still, wherever cliffs occur, they afford good sections, and deserve examination. One question will usually present itself to almost every geological observer, and that is, whether any coast he may be landing upon affords evidence of elevation or depression. In the former case, beds of rolled pebbles or of marine shells, similar to those now living on the shore, may be found at some elevation above high-water mark. Very often the commonest molluscs in raised beds are the kinds occurring in estuaries, which are different from those inhabiting an open coast. Caution is necessary, however, that heaps of shells made by man, or isolated specimens transported by animals (birds or hermit-crabs), or by the wind, be not mistaken for evidence of raised beds. If the shore is steep, terraces on the hill-sides may mark the levels at which the sea remained in past times, but some care is necessary not to mistake outcrops of hard beds for terraces. If dead shells of species of mollusca, only living in salt-water estuaries, are found in places now beyond the influence of the tide, it is a reasonable inference that elevation has taken place.

The evidence of depression, on the other hand, unless there are buildings or trees partly sunk in the water, is much less readily obtained, and neither trees nor buildings are available as evidence, unless the depression is of comparatively recent date. The best proof is the form of the

coast. If deep inlets of moderate breadth occur, with numerous branches, a little examination will frequently show whether such inlets are valleys of subaërial erosion, as they not unfrequently are, that have been depressed below the sea. A good and familiar example of such a depressed valley is to be found at Milford Haven in South Wales. In higher latitudes, care must be taken not to mistake glacier valleys, such as the friths and lochs of Scotland, and the fiords of Norway, for valleys of subaërial erosion that have recently undergone subsidence. It is highly probable, even in this case, that the valleys were originally formed by fresh-water denudation, and that they have been depressed, but their features have been modified by the action of ice.

Rivers and River-Plains.—At the present time a question of much interest is the antiquity of existing land-areas, and some light may be thrown upon this, if the relations of existing river-basins to those of past times can be determined. If a stream cuts its way through a high range, it is probable that the stream is of greater antiquity than the range, and either once ran at an elevation higher than the crest of the ridge now traversed, or else has cut its way through the range gradually during the slow elevation of the latter. Where a river traverses a great alluvial plain, it may fairly be inferred that a long time has been occupied in the accumulation of the deposits to form the plain; but it remains to be seen whether those deposits are not partly marine or lacustrine. If upheaval has taken place over any portion of the plain, or if the river has cut its bed deeper, sections may be exposed, and these should always be examined for fossil remains. Bones of extinct animals are not unfrequently found in such deposits.

Lakes.—The mode of origin of lakes is always a subject of considerable geological interest. Some lakes occupy areas of depression; others valleys of erosion, the drainage from which has been stopped by local elevation, by land-slips, or by deposits from tributaries, whilst very many, and amongst them some of great size and depth, occur in regions that have been covered by ice; and it is still a moot point how far these lakes are due to partial changes in the elevation of the country, some observers having adopted, while others dispute the views of the late Sir A. Ramsay, who believed all these hollows to have been scooped out by ice moving over the surface in the form of a glacier or of an ice-sheet. Of the smaller lakes, some are dammed

up by landslips, some by glacial moraines, and a few occupy volcanic craters.

Evidence of Glacial Action.—Closely connected with the subject of lakes is that of glacial evidence generally. There is probably no geological question which has produced more speculation of late years than the inquiry into the traces of a comparatively recent cold period in the earth's history. Closely connected with this inquiry is the equally important question as to the former occurrence of similar glacial epochs at regular or irregular intervals of geological time.

The evidence of the last glacial epoch may be traced in two ways—by the form of the surface, which has been modified by the action of ice, and by changes that have taken place in the fauna and flora of the country in consequence of the alteration in the climate. The effects of an ice-sheet, like that now occurring in Greenland, if such formerly existed in comparatively low latitudes, must have been to round off, score and polish the rocks of the country in a peculiar manner, easily recognised by those familiar with glaciated areas.* Glaciers, properly so called, are confined to hilly or mountainous countries, and the valleys formerly occupied by them retain more or less the form of the letter U instead of taking the shape of the letter V, as they do when they have been cut out by running water. The sides of the valley, when modified by a glacier, have a tendency to assume the form of slopes unbroken by ravines, and with all ridges planed away or rounded, whilst in ordinary valleys of erosion by water, the sides consist of a series of side valleys or ravines, divided from each other by sharp ridges running down to the main valley. Large and small masses of rock, preserving to a considerable extent an angular form, but frequently polished and grooved by being ground against the sides or bottom of the valley, are carried down by the ice, and either left behind, perched up high on the slopes of the valley, or accumulated in a vast heap or bank, known as a terminal moraine, at the spot where the ice has terminated. The nature of the rock will usually show whether the fragments on the side of a hill or at the bottom of a valley are derived from the higher parts of the drainage area, or whether

* Care should be taken that the peculiar scoring and grooving of rock surfaces produced by the action of sand transported by the wind be not mistaken for glacial evidence.

they have merely fallen down from the neighbouring slopes. In the latter case, they may be due to landslips; in the former, their shape and the erosion they have undergone will aid in showing whether they have been transported by water or ice.

The surfaces that have been modified by earlier glacial epochs must in general have been long since removed by other denuding agencies. The most important evidence of former ice action consists in the occurrence, embedded in fine sediment, of large boulders, occasionally preserving marks of polish and striation, and usually, though not always, angular.

It is well to search in all mountain ranges for traces of glacial action. In many mountain chains, even in comparatively low latitudes, proofs have been found of the existence of glaciers, at a much lower level than at present, dating from a comparatively recent geological period, whilst in other mountain regions none have been recognised. The question also whether glacial action has been contemporaneous in the two hemispheres is of the greatest importance, and the evidence hitherto adduced is of a very conflicting character.

Deserts.—The great sandy or salt plains, with a more or less barren surface, that occupy a large area in the interior of several continents, have only of late years received due attention from geologists. A great thickness of deposits must occur in many of these vast, nearly level tracts, for the underlying rocks are often completely concealed over immense areas. The investigation of the deposits is frequently a matter of great difficulty for want of sections; but, where practicable, a careful examination should be made, and exact descriptions of the formations exposed recorded. Some, at all events, of these beds appear to be entirely deposited from the air, and consist of the decomposed surfaces of rocks and the sand and silt from stream deposits, carried up by wind and then redeposited on the surface of the country. Such deposits are very fine, formed of well-rounded grains, and, as a rule, destitute of stratification. The geologist who has especially described these formations, Baron F. von Richthofen, in his work on China, attributes to the loess of the Rhine and Danube valleys a similar origin. It is usual to find beds due to water-action, rain-wash and steam-deposits, interstratified with the subaërial accumulations. Further observations on these formations are desirable. The occurrence of blown sands, the origin of these accumulations, and the

peculiar ridges they assume, usually at right angles, but in some remarkable cases parallel to the prevailing winds, are questions deserving of additional elucidation.

Early History of Man in Tropical Climates.—Very little has been discovered as to the races of men formerly inhabiting tropical regions. It is evident that a race unacquainted with fire could only have existed in a country where suitable food was procurable throughout the year, and this must have been in a region possessing a climate like that found in parts of the tropics at the present day. It is possible that an investigation of the cave deposits in the tropics may throw some light on this subject. "Kitchen middens," as they are termed—the mounds that have once been the refuse heaps of human habitations—are also worthy of careful examination.

Permanence of Ocean-Basins.—Within the last few years some geologists have adopted the theory that all the deep-sea area has been the same from the earliest geological times, and that the distinction between the depressions occupied by the oceans and the remaining undepressed portion of the earth's crust, constituting the continents and the shallow seas around their coasts, is permanent. This view is very far from being universally or even generally accepted amongst geologists, although many who hesitate to accept the theory as a whole admit that parts of the oceans have in all probability been deep basins since the earth's crust was first consolidated.

The argument on both sides depends upon theories to which travellers can contribute but little except by observations on the geology, fauna, and flora of oceanic islands, and by the investigation of coral-reefs and especially of atolls. In ranges of hills or mountains near the coasts both of continents and islands and in all tracts where evidence of recent elevation exists, search should be made for deep-sea deposits. These are fine calcareous or argillaceous beds, often containing small Foraminifera or Radiolaria, which, however, are generally extremely minute, and require microscopical examination for detection. If any beds of consolidated calcareous ooze or especially if red or grey clay be found associated with pelagic deposits, such as coral limestone, a few small fragments of such beds should always be brought away for examination, and any distinct fossil remains found in sunk beds, such as echinoderms (sea-urchins or star-fishes) or sharks' teeth, should be carefully preserved

with some of the matrix. Deep-sea deposits have recently been discovered in several parts of the world, for instance, the West Indies, the Solomon Islands, and the islands of Torres Straits.

Atolls or Coral-Islands.—The remarkable coral islands of the Pacific and Indian oceans consist usually of an irregular ring, part or the whole of which is a few feet above the sea, and which encircles an inner lagoon of no great depth in general. The outer margin of the reef around each island slopes rapidly, sometimes precipitately, to a depth of, usually, several hundred fathoms. Darwin, taking these facts into consideration, together with the circumstance that no coral reefs are known to be formed at a greater depth than about 15 to 20 fathoms, showed that all the facts of the case could be explained by the theory that coral-islands were formed in areas of subsidence. This view was generally accepted until lately, when Mr. Murray and other writers have brought forward evidence in favour of coral-islands being founded on shoals that may be areas of elevation.

The only crucial test of depression would be a series of borings through the coral limestone of a typical atoll to a depth of 300 or 400 feet. Prof. J. D. Dana has shown that coral rock has been found at a depth of more than 800 feet in borings near Honolulu in the Sandwich Islands; but the case is not typical, and the cores from the borings did not receive a sufficiently thorough examination to prove their origin as reef-coral. Fresh observations on the limits of depth to which reef-forming corals are confined would be valuable. Meantime any additional details would be useful, such as careful soundings around atolls, so as to give an accurate profile of the sea-bottom in the neighbourhood.

MEMORANDUM ON GLACIER OBSERVATIONS.

Issued by the Committee of the Alpine Club.

The recent movements of glaciers may be noted by the following signs:—

When the ice is advancing, the glaciers generally have a more convex outline, the icefalls are more broken into towers and spires, and piles of fresh rubbish are found shot over the grass of the lower moraines. Moraines which have been comparatively recently deposited by advancing ice are disturbed, show cracks, and are obviously being pushed forward or aside by the glacier.

When the ice is in retreat, the marks of its further recent extension are seen fringing the glacier both at the end and sides in their lower portions, the glacier fails to fill its former bed, and bare stony tracts, often interspersed with pools or lakelets, lie between the end of the glacier and the mounds of recent terminal moraines.

Where a glacier has retreated to any considerable extent, careful observations of the form of its bed are of value. What is the nature of the rock surfaces exposed—convex or concave; are they rubbed smooth on their leesides; how far have the contours of the cliffs or slopes, or the sides of any gorge, been modified where they have been subjected to ice-friction? Is there any evidence that the ice has flowed over large boulders, or loose soils, such as gravel, without disturbing them? How has it affected rocks of different hardness, for instance, veins of quartz in a less hard rock? Generally, do the appearances indicate that the glacier has excavated, or only abraded and polished its bed; that it has scooped out new rock-basins, or only cleaned out, scratched, and preserved from filling-up by alluvial deposits or earthslips, existing basins? What is the general character of the valley bottom and slopes above and below the most conspicuous ancient moraines?

The depth of mountain lakes and the position of the point of greatest depth should be ascertained wherever possible. The marginal rock structure of lake basins, particularly near their outlet, is of some importance with a view to ascertaining whether they are true rock basins,

or whether they are reservoirs formed by ancient moraines, earthslips, or alluvial deposits.

The traveller or surveyor should, if possible, paint a mark and date on any conspicuous rock *in situ* parallel with the termination of the glacier at the time of his visit, marking the distance in yards of the ice from it. The next visitor will then be able to measure the movement that has taken place since his predecessor's visit. Leaving out of question elaborate trigonometrical methods, such, for instance, as have been carried out on the Rhone Glacier in Switzerland, the following plan gives very valuable results, and demands no other instruments than a small jar of paint, a brush, a measuring tape, and a pocket compass. To ascertain the recent retreat of a glacier, measure the distance from the end of the ice in front of the longitudinal axis of the glacier to the most advanced terminal moraine, where vegetation first shows itself. The bare ground recently left by glaciers is easily recognisable. The diminution of volume is best measured by ascertaining the height of bare soil left on the sides of the lateral moraines in the portion of the glacier within the zone of vegetation. All photographic representations of the glacier end, and of the ground which has been freed from the glacier ice, are of great value. Those will be of most service that show the position of the glacier-snout with relation to some conspicuous rock or other feature in the local scenery. Each photograph should be dated, and the bearings and distance of the camera with reference to any such feature accurately noted.

It is very important to investigate the state of various glaciers as regards advance or retreat. Neighbouring glaciers often furnish very different results in this respect, owing to the fact that steep glaciers anticipate in their oscillations those the beds of which are less inclined. To ascertain the oscillations of glaciers, it is necessary to fix the actual position of the ice-snout at the end of the glacier with the greatest accuracy. Two methods can be employed for this purpose, either of which may be selected according to circumstances.

Paint some signs on large boulders, not too far from the end of the glacier, and measure their distance from it by a tape (Richter's system), or build a low wall of stones of a few yards in length, and, say 15 to 20 inches in height, some distance from the ice-end, and measure this distance (Gosset's system). It is to be recommended that the stones of these walls

should also be painted. If the traveller himself returns after some interval—even after only two or three weeks—he will be able to judge of the movement of the glacier, and he will have laid down a basis for further observations by future travellers.

One of the results most to be desired is an exact knowledge of the dates:

I. Of the maximum extension of the ice.
II. Of the commencement of retreat.
III. Of the minimum.
IV. Of the commencement of fresh increase.

In dealing with a mountain group, therefore, the traveller should note (where he can get the information as to the past) the date of the commencement of the actual movement of *each glacier*, and in all cases whether the ice is in advance, or retreat, or stationary. Of course the rate of forward movement, or velocity of the ice, and the oscillations in the extension of the ice must be kept carefully distinct.

Should time and circumstances permit, a series of observations of the velocity of the ice is of value. These may be made after Tyndall's method, by planting a line of sticks across the glacier, or by painting marks on boulders, the position of which relatively to ascertained points on the mountain-side has been accurately fixed. The size of the glacier, that is, the area of its basin and its length, as well as the slope of its bed above, as well as at the point measured, should be noted. The rate of movement of the ice appears to be connected both with the volume of the glacier and the inclination of its bed.

VIII.

NATURAL HISTORY.

By H. W. Bates, F.R.S.

Revised by P. L. Sclater, F.R.S.

In the present state of biological science, travellers who intend to devote themselves specially to the zoological or botanical investigation of new or little-known countries, require to be trained for the work beforehand, and will be necessarily well-informed as to methods and appliances. It is not for them that these 'Hints' are drawn up, but for general travellers and explorers, who, whilst engaged chiefly in survey, wish to know how best to profit by their opportunities of benefiting science by collecting examples of new or rare species, and how to preserve and safely transmit their specimens. The observations refer only to explorations by land.

*Outfit.**—A double-barrel gun; for large aquatic birds, &c., a breech-loader to be preferred, and wire cartridges. For Central Africa, and regions where large mammals are found, a more powerful weapon is also required. Mr. Thomson took with him on his Masai Land expedition a breech-loading 8-gauge elephant gun, double-barrel, smooth bore, and weighing about 11 lbs., and fitted with a thick Silver's patent anti-recoil heel-plate; with its leather cover, powder measure, bullet-fixer and mould, &c.

If percussion-cap guns are used, fine powder in canisters, and fine shot, must be taken from England; coarse powder and shot can be had at any

* Implements, &c., for collecting and preserving birds, insects, &c., can be obtained of Mr. Janson, 44, Great Russell Street, W.C., or Messrs. Watkins and Doncaster, 36, Strand, W.C.; for the larger animals, as well as other articles of general travelling outfit, of Messrs. Silver and Co., 67, Cornhill, and Old Bond Street, W.

trading settlement. A good supply of the best caps and a few spare nipples should be taken, as also the following articles :—

Arsenical soap in tin boxes; brushes of different sizes for applying the same; a small supply of carbolic acid, and a few insect "killing bottles."* Bottle of rangoon oil. Scalpels, scissors (including a pair of short-bladed ones), needles and thread. Long straight forceps (similar in form to curling irons), very useful for inserting cotton into the necks of bird-skins, to avoid stretching them; of two or three sizes. Bone nippers and screw-driver.

A few small traps, with which to capture small (mostly nocturnal) mammals. The "Excelsior" and "Premier" traps, always set and baited, are recommended, as they capture small mammals without injuring them. For spring traps the "American wire-trap" is to be preferred, as they are very light and of different sizes, and a large number weigh little and occupy small space.

Stone jars for reptiles and fishes in spirit; to fit four in a box, with wooden partitions. If animals in spirit are to be collected largely, the tin collecting-case described further on, and a supply of sheet-tin or zinc, with a pair of soldering-irons and a sufficient quantity of soft solder, must be taken instead of, or in addition to, stone jars. Cylindrical cases can then be made of any size required. By means of the soldering apparatus also empty powder-canisters, and other tin vessels, can be easily converted into receptacles for specimens.

A short landing-net for water-molluscs and other small aquatic animals. A stout hoop-net (the stick 4 or 5 feet long crossing the hoop) for capturing insects on the wing and for sweeping herbage for Coleoptera, &c.; a few yards of silk gauze for nets in reserve.

* These bottles are for collecting all kinds of hard-bodied insects on an excursion, and should be of a size to fit the pocket, strong, and with broad mouths. The insecticide paste adhering to the bottom can be easily made by the traveller. A pellet of cyanide of potassium (the size of a pea) must be dissolved in water in the bottle, and sufficient powdered plaster of Paris mixed with it until the water is absorbed, when the whole should be pressed down into a hard cake an inch in thickness. A simpler plan is, a pellet of cyanide wrapped in paper placed in the bottle half full of coarse-grained sawdust; at a pinch, a small quantity of spirits in the bottle will do; but the insects must on no account be left more than a day or two in the spirit.

A supply of triangular paper envelopes for Lepidoptera, &c. Boxes of light wood of various sizes (about the size of cigar-boxes) for storing and packing specimens. Tin boxes may be used in very damp climates, provided the contents are well dried before storing; and the general outfit of an expedition may be much lightened by having all the provisions, and other consumable articles, packed in tin cases, and in boxes and jars of such forms as may render them available for containing specimens.

As a preservative against the attacks of insect vermin, a supply of "Papier Préservateur" will be found most useful. Each box should be wrapped in a sheet of this paper.

In humid tropical countries, where the ubiquitous ants are likely to destroy specimens before they are ready to be packed away, drying-cages, suspended from the roof of a hut or tent, are absolutely necessary. These can be readily made from old packing-cases, but a few square feet of wire gauze must be provided for the back and front of the cages, and the cord by which they are suspended must be threaded through a small calabash containing oil, to prevent ants from descending from the roof. The cages may be so arranged as be taken to pieces and put together again readily; one, for birds, should be about 2 feet 6 inches long by 1 foot 6 inches high and 1 foot broad; the other, for insects and other small specimens, may be about one-third less. They should have folding doors in front, with panels of wire gauze, and the backs wholly of the latter material; the sides fitted with racks to hold six or eight plain shelves, which in the smaller cage should be covered with cork, or any soft wood that may be obtained in tropical countries. A strong ring fixed in the top of the cage, with a cord having a hook attached at the end by which to hang it in an airy place, will keep the contained specimens out of harm's way until they are quite dry, when they may be stowed away in their close-fitting boxes.

A few yards of india-rubber waterproof sheeting, as temporary covering to collections in wet weather, or in crossing rivers.

A set of carpenter's tools for making boxes and packing-cases.

Where and what to collect.—The countries which are now the least known with regard to their natural history, are New Guinea and the large islands to the east of it, Northern Australia, the interior of Borneo, Tibet, Indo-China, and other parts of Central Asia, Equatorial Africa,

and the eastern slopes of the Andes, from Bogota to Bolivia. A special interest attaches to the indigenous productions of oceanic islands, *i.e.* islands separated by a deep sea from any large tract of land. Those who have opportunities could not fail to make interesting discoveries by collecting specimens of the smaller animals (insects, molluscs, &c.) and plants in these isolated localities. Both in continental countries and on islands the truly indigenous species will have to be sought for on hills and in the remote parts, where they are more likely to have escaped extermination by settlers and the domestic animals introduced by them. In most of the better-known countries the botany has been better investigated than the zoology, and in all there still remains much to be done in ascertaining the exact station, and the range, both vertical and horizontal, of known species of animals and plants. This leads us to one point, which cannot be too strongly insisted on, namely, that some effective means should be adopted by the traveller to record the *exact locality* and *date* of every specimen he collects. With regard to the larger dried animals this may be done by written tickets attached to the specimens; if insects are pinned, a ticket may be fixed on the pins; and if packed unpinned in boxes, all taken in one place should be laid together, and a common label placed with them. When all the specimens taken at one place can be put into a separate box, one memorandum upon the box itself will be sufficient. Reptiles and fishes should have small parchment tickets attached to them before they are placed in spirits, and the writing on them should be in pencil, not in ink. In mountainous countries, the approximate height above the sea should be noted.

A traveller may be puzzled, in the midst of the profusion of animal and vegetable forms which he sees around him, to know what to secure and what to leave. Books can be of little service to him on a journey, and he had better at once abandon all idea of encumbering himself with them. A few days' study at the principal museums before he starts on his voyage may teach him a great deal, and the cultivation of a habit of close observation and minute comparison of the specimens he obtains will teach him a great deal more. As a general rule, all specimens which he may meet with for the first time far in the interior should be preferred to those common near the civilised parts, and he should bear in mind that the few handsome kinds which attract the attention of the natives and are

offered for sale to strangers are almost sure to be of species well known in European museums. He should strive to obtain as much variety as possible, and not fill his boxes and jars with quantities of specimens of one or a few species. But as some of the rarest and most interesting species have great resemblance to others which may be more common, he should avail himself of every opportunity of comparing the objects side by side. In most countries, as already remarked, the truly indigenous, and often the rarest, species are to be found only in the mountains at considerable elevations and in the primitive forests, the products of cultivated districts being nearly all widely distributed and well known. In botany a traveller, if obliged to restrict his collecting, might confine himself to those plants which are remarkable for their economical uses; always taking care to identify the flowers of the tree or shrub whose root, bark, leaves, wood, &c., are used by the natives, and preserving a few specimens of them. But if he has the good fortune to ascend any high mountain not previously explored, he should make as complete a collection of the flowering plants as possible, at the higher elevations. The same may be said of insects found on mountains, where they occur in great diversity—on the shady and cold sides rather than on the sunny slopes—under stones, and about the roots of herbage, especially near springs, on shrubs and low trees, and so forth; for upon a knowledge of the plants and insects of mountain ranges depend many curious questions regarding the geographical distribution of forms over the earth. In reptiles, the smaller Batrachians (frogs, salamanders, &c.) should not be neglected, especially the extremely numerous family of tree-frogs; lizards may be caught generally with the insect sweeping-net; the arboreal, or rock haunting species seen out of reach, and the swift-running forms that inhabit sandy plains may be brought down with a charge of dust-shot. Snakes should be taken without injuring the head, which is the most important part of the body: a cleft stick may be used in securing them by the neck, or they may be shot, and on reaching camp they may be dropped into the jars of spirits. As large a collection as possible should be made of the smaller fishes and tortoises of lakes and rivers.

Mammals and Birds.—An ordinary geographical expedition will hardly have the means at its disposal for bringing home many specimens of the larger animals. But many species in regions visited only by adventurous explorers are still desiderata in the large museums of Europe; and

additional specimens of all genera of which there are numerous closely-allied species (*e.g.* rodents, antelope, deer, &c.), and of all the small nocturnal mammals would be welcome to zoologists. If only portions can be obtained, skulls with horns attached are to be preferred. In humid tropical regions entire skins cannot be dried in time to prevent decay, and it is necessary to place them rolled up in a small compass, in spirits. The smaller birds shot on an excursion should be carried to camp in the game-bag, folded in paper, the wounds, mouth and anus being first plugged with cotton. Powdered calcined gypsum will here be found very useful in absorbing blood from feathers, on account of the facility with which it can be afterwards cleared from the specimens. Dull-coloured and small birds are most likely to be new or interesting.

Immediately after killing a small mammal or bird, make a note of the colour of its eyes and soft parts, and, if time admits, of the dimensions of its trunk and limbs. It facilitates skinning of birds to break, before commencing, the first bone of the wings a short distance above the joint, which causes the members to lie open when the specimen is laid on its back on the skinning-board. The animal should be laid with its tail towards the right hand of the operator, and the incision made from the breast-bone nearly to the anus. A blunt wooden style is useful in commencing the operation of separating the skin from the flesh. When the leg is reached, cut through the knee-joint and then clear the flesh from the shank as far as can be done, afterwards washing the bone slightly with arsenical soap, winding a thin strip of cotton round it, and returning it to the skin. Repeat the process with the other leg, and then sever, with the broad-bladed scissors, the spine above the root of the tail. By carefully cutting into the flesh from above, the spine is finally severed without injuring the skin of the back, and it is then easy to continue the skinning up to the wings, when the bones are cut through at the place where they had previously been broken, and the body finished as far as the commencement of the skull. A small piece of the skull is now cut away, together with the neck and body, and the brains and eyes scooped out, the inside washed with the soap, and clean cotton filled in, the eyes especially being made plump. In large-headed parrots, woodpeckers, and some other birds, the head cannot thus be cleaned; an incision has, therefore, to be made either on one side or on the top of the head, through which the back of the skull can be thrust a little away and then cleansed, the incision being after-

wards closed by two or three stitches. The bones then remaining in each wing must be cleaned, which must be done without loosening the quill-feathers. It is much better to take out the flesh by making an incision on the outside of the skin along the flesh on the inner side of the wing. The inside of the skin must now be washed with the soap, and a neck of cotton (not too thick) inserted by means of the long narrow forceps, taking care to fix the end well inside the skull, and withdrawing the empty forceps without stretching the skin of the neck, and thus distorting the shape of the bird. Skins need not be altogether filled up with cotton or any other material, but laid, with the feathers smoothed down, on the boards of the drying-cage until they are ready to be packed in boxes. Each skin should be kept in a separate roll of brown paper, and store boxes should be lined with brown paper, which is avoided by insects. In very humid climates, like that of Tropical America, oxide of arsenic in powder is preferable to arsenical soap, on account of the skins drying more quickly; but it cannot be recommended to the general traveller, owing to the danger attending its use.*

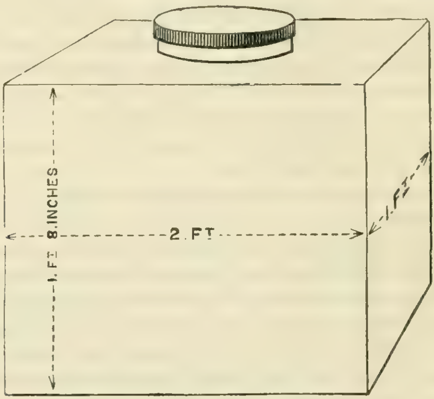
In mammals the tail offers some difficulty to a beginner. To skin it, the root (after being severed from the spine) should be secured by a piece of strong twine, which should then be attached to a nail or beam; with two pieces of flat wood (one placed on each side of the naked root), held firmly by the hand and pulled downwards, the skin is made rapidly to give way generally to the tip. The tails of some animals, however, can be skinned only by incisions made down the middle from the outside. The larger mammal skins may be inverted, and, after washing with the soap, dried in the sun; as before remarked, it is often necessary to roll them up and preserve them in spirit.

The skins of small mammals and birds, after they are *quite* dry, may be packed in boxes, which must be previously well washed inside with arsenical soap, lined with paper, and again covered with a coating of the soap and well dried in the sun. This is the very best means of securing the specimens from the attacks of noxious insects, which often, to the

* For further information about collecting birds, formula for making arsenical soap, &c., we may refer the traveller to Hume's 'Collector's Vade Mecum' (Quaritch, London. Price 2*s*.), and 'Directions for Collecting Birds,' issued by the Smithsonian Institution, Washington, 1891–92.

great disgust of the traveller, destroy what he has taken much pains to procure. When wood is scarce, as in the interior of Africa, boxes may be made of the skins of antelopes or other large animals by stretching them, when newly stripped from the animal, over a square framework of sticks, and sewing up the edges: after being dried in the sun they make excellent packing-cases.

Preserving Mammals, &c., in Alcohol.—In the interests of science the preservation, in alcohol, of mammals, as well as of reptiles, fishes and crustacea, is to be preferred, and the traveller is earnestly recommended



General Collecting-Case.

to adopt this plan, especially with regard to the smaller specimens, dried skins of which are almost useless for scientific purposes. On this subject Dr. G. E. Dobson sends us the following 'Hints':—

The general collecting case should be made of strong block tin, rectangular in form, about 2 feet × 1 foot × 1 foot 8 inches in height, having in the top a circular aperture from 6 to 8 inches in diameter, closed by a well-fitting brass-screw cap, the flange of which is made air-tight by a well-greased leather collar. This should fit accurately into a similarly shaped box of inch boards, having a simple flat lid (not projecting beyond the sides), secured by eight long screws, and provided with a strong iron

handle. This case should be filled with the strongest methylated spirits procurable (in foreign countries over-proof rum, brandy, or arrack will suit equally well). If circumstances admit, two or more such cases should be taken, or four wide-mouthed earthenware jars placed in a square wooden case and separated by light wooden partitions, having their mouths closed by well-fitting bungs tied down with bladder and skin. On arrival at the collecting station one of the jars should be half filled with spirit from the tin case. Into this each specimen, as it is obtained, having a long slit made in the side of the abdomen, should be put, and allowed to remain 24 hours before being transferred to the general collecting case. When the latter can hold no more, the specimens should be removed one by one and packed in the moist state in the other wide-mouthed jars, one above the other, like herrings in a cask, each rolled in a piece of thin cotton cloth, in which a label, having the locality and date written in pencil, should be placed. When the jar has been thus filled to the mouth a glass or two of the strong spirit (kept in reserve) should be poured in so as to fill up interstices, but not to appear on the surface, which should be covered with a thick layer of cotton-wool. A few drops of carbolic acid, if the spirit be weak, will greatly aid its preserving powers. The bung should then be replaced, secured round the margin outside with a mixture of tallow and wax, and tied down securely with bladder or skin, and the name of the collector and district written legibly outside. The jar is now ready for transmission to any distance, for specimens thus treated will keep good in the vapour alone of strong spirit for months. Other jars may be filled in like manner, and, finally, the general collecting case. Incisions should invariably be made in the *sides* (not in the centre line) of all animals, so as to allow the spirit to enter, and no part of the intestines should be removed. In the case of *tortoises* the opening may be made in the soft parts round the thighs; if this be not done the body soon becomes distended with gases. *Frogs* should always be first placed in weak spirit, and after being soaked for one or two days, be removed to strong alcohol. *Crabs* should be rolled up alive in thin cotton-cloths, secured by thread tied round; they are then readily killed by immersion in alcohol; if this be not done they lose many of their limbs in their dying struggles.

Preparation of Skeletons of Animals.—In many cases it will be found impossible to preserve the whole animal, especially if of large size, but it

may advantageously be converted into a skeleton by attention to the following directions of Sir W. H. Flower, F.R.S.:—

If the animal is of small size—say not larger than a fox—take off the skin except from the feet below the wrist and ankle joints. If it is intended to preserve the skin as a zoological specimen as well as the skeleton, the bones of the feet should all be left in the skin; they can be easily extracted afterwards, and will be preserved much more safely in their natural covering. Remove all the contents of the abdominal and thoracic cavities; also the larynx, gullet, and tongue. In doing this be careful to leave attached to the base of the skull the chain of bones which supports the root of the tongue. These may either be left in connection with the skull, or cleaned separately and tied to the skeleton. Then clear away, with the aid of a knife, as much as possible of the flesh from the head, body, and limbs, without cutting or scraping the bones, or separating them from each other. At any intervals that may be necessary during this process it will be desirable, if practicable, to leave the body in water, so as to wash away as much of the blood as possible from the bones, and a few days' soaking in water frequently changed will be an advantage.

The body, with all the bones held in connection by their ligaments, should then be hung up to dry in a place where there is a free current of air, and out of the way of attacks from animals of prey. Before they get hard the limbs may be folded by the side of the body in the most convenient position, or they may be detached and placed inside the trunk.

When thoroughly dry the skeletons may be packed in boxes with any convenient light packing material between them. Each should be well wrapped in a separate piece of paper or canvas, as sometimes insects will attack the ligamentary structures and allow the bones to come apart.

If it can be avoided, skeletons should never be packed up so long as any moisture remains in them, as otherwise decomposition will go on in the still adhering soft parts, and cause an unpleasant smell.

If the animal is of larger size, it will be most convenient to take it partially to pieces before or during the cleaning. The head may be separated from the neck, the vertebral column divided into two or more pieces, and the limbs detached from the trunk; but in no case should the small bones of the feet be separated from one another. The parts

should then be treated as above described, and all packed together in a canvas bag.

In the cetacea (porpoises, &c.), look for two small bones suspended in the flesh, just below the vertebral column, at the junction of the lumbar and caudal regions (marked externally by the anal aperture). They are the only rudiments of the pelvis, and should always be preserved with the skeleton.

If there is no opportunity of preserving and transporting entire skeletons, the skulls alone may be kept. They should be treated as above described, picked nearly clean, the brain being scooped out through the *foramen magnum*, soaked for a few days in water, and dried.

Every specimen should be carefully labelled with the scientific and popular name of the animal, if known, and at all events, with the sex, the exact locality at which it was procured, and the date.

For the purpose of making entire skeletons, select, if possible, adult animals; but the skulls of animals of all ages may be advantageously collected.

Collectors of skins should always leave the skull intact. The common practice of destroying its hinder part for the purpose of getting out the brain is unnecessary, and greatly diminishes the value of the specimens.

Reptiles and Fishes.—The following 'hints' have been communicated by Mr. Osbert Salvin, F.R.S., who collected these animals most successfully in Guatemala:—

Almost any spirit will answer for this purpose, its fitness consisting in the amount of alcohol contained in it. In all cases it is best to procure the strongest possible, being less bulky, and water can always be obtained to reduce the strength to the requisite amount. When the spirit sold retail by the natives is not sufficiently strong, by visiting the distillery the traveller can often obtain the first runnings (the strongest) of the still, which will be stronger than he requires undiluted. The spirit used should be reduced to about proof, and the traveller should always be provided with an alcoholometer. If this is not at hand, a little practice will enable him to ascertain the strength of the spirit from the rapidity with which the bubbles break when rising to the surface of a small quantity shaken in a bottle. When the spirit has been used this test is of no value. When reptiles or fish are first immersed, it will be found that the spirit becomes rapidly weaker. Large specimens absorb the

alcohol very speedily. The rapidity with which this absorption takes place should be carefully watched, and in warm climates the liquid tested at least every twelve hours, and fresh spirit added to restore it to its original strength. In colder climates it is not requisite to watch so closely, but practice will show what attention is necessary. It will be found that absorption of alcohol will be about proportionate to the rate of decomposition. Spirit should not be used too strong, as its effect is to contract the outer surface, and thus, closing the pores, to prevent the alcohol from penetrating through to the inner parts of the specimen. *The principal point, then, is to watch that the strength of the spirit does not get below a certain point while the specimen is absorbing alcohol when first put in.* It will be found that after two or three days the spirit retains its strength: when this is the case, the specimen will be perfectly preserved. Spirit should not be thrown away, no matter how often used, so long as the traveller has a reserve of sufficient strength to bring it back to its requisite strength.

In selecting specimens for immersion, regard must be had to the means at the traveller's disposal. Fish up to 9 inches long may be placed in spirit, with simply a slit cut to allow the spirit to enter to the entrails. With larger specimens, it is better to pass a long knife outside the ribs, so as to separate the muscles on each side of the vertebræ. It is also as well to remove as much food from the entrails as possible, taking care to leave all these in. The larger specimens can be skinned, leaving, however, the intestines in, and simply removing the flesh. Very large specimens preserved in this way absorb very little spirit. All half-digested food should be removed from snakes and animals. In spite of these precautions, specimens will often appear to be decomposing; but, by more constant attention to re-strengthening the spirit, they will, in most cases, be preserved.

A case (copper is the best), with a top that can be unscrewed and refixed easily, should always be carried as a receptacle. The opening should be large enough to allow the hand to be inserted; this is to hold freshly-caught specimens. When they have become preserved, they can all be removed and soldered up in tin or zinc boxes. Zinc is best, as it does not corrode so easily. The traveller will find it very convenient to take lessons in soldering, and to be able to make his own boxes. If he takes them ready made, they had best be arranged so as to fit one into

another before they are filled. When moving about, all specimens should be wrapped in calico or linen or other rags to prevent their rubbing one against the other. This should also be done to the specimens in the copper case when a move is necessary, as well as to those finally packed for transmission to Europe. These last should have all the interstices between the specimens filled in with cotton-wool or rags. If a leak should occur in a case, specimens thus packed will still be maintained moist, and will keep some time without much injury. Proof spirit should be used when the specimens are finally packed, but it is not necessary that it should be fresh.

*Land and Freshwater Mollusca.** By LIEUT.-COL. H. H. GODWIN-AUSTEN, F.R.S.—Always most abundant on limestone rocks. Search for under the larger stones lying about the ground, and under fallen trees and logs in the woods and forests. Will be generally found adhering to the surface of the stone or wood. Many species are often only 0·05 inch in length, so that very close examination is necessary. In damp spots, generally in ravines with a northerly aspect, the dead leaves when damp with dew in the early morning may be turned over one by one, and the under surface examined for minute species, and larger species will be found very frequently on the surface of the ground below the layer of decaying vegetable matter. Tear off the bark of decaying trees also. In the drier parts of the country some species are only to be found among the roots of shrubs, and at considerable depth; by digging them out and shaking the earth on to paper, small shells may be found on close examination. At a dry place like Aden, I should expect to find most of the land-shells alive in such a habitat. Look well in caves in limestone on the damp surface of the rock; some forms hide themselves under a coating of earthy matter. Search also on damp moss and rock near waterfalls.

Some species will be found high up on the bushes and trees. This is the habit of certain African forms especially; not so in India. A very good idea may at first be obtained of the land-shells of a country by the examination of the beds of the streams, either along the highest flood-line, or in the fine sand and mud where it collects in the bed; such land-shells will usually be old and bleached, but the living specimens will not be far off.

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* Much useful information may be found in the 'Manual of the Mollusca,' by S. P. Woodward, F.G.S., one of Weale's series: an admirable book in a small form.

The leaves and stems of water plants should be examined, and Confervæ taken out of the water and well washed in a basin; in this, and the mud of ponds and still rivers, many minute shells may be found.

The best way of preserving minute shells is to put them into glass tubes and use wool to stop them; it is better than cork. Capital collecting tubes can be made out of the smaller sorts of bamboo and the large grasses. A certain number of every species (at least a dozen) should be preserved in spirit for the sake of the anatomy. It is best to kill them first in water and then put them into the spirit; if this is not done they contract, so that it is impossible to form any idea of the form of the mantle and other parts, and they become so hard they are difficult to cut up.

A good method of keeping the small shells and slugs, especially in spirit, is to put them into small tubes with labels, plug with wool, and then place in a large jar, capable of holding three or four dozen such small tubes.

Other small shells, ½ to ¾ of an inch in diameter, may be put into pill-boxes at once, for in a dry climate they very soon dry up. The very large animals may be removed by boiling them in water, but when time does not admit of attending to the cleaning of the shells, species such as unios may be put into empty soup-tins and then filled up with dry sand.

It is very important to make a few notes on the colour of the animal, attaching a number for reference on the box or in the tube, and the operculum, when present, should always be preserved.

With respect to slugs, note the surface of the mantle, and always the form of the extremity of the foot, whether pointed or provided with a mucous pore; and again the lobes of the mantle. Preserve them in spirit as above. Drawings from the living animal are invaluable, and should be made if possible. Very little is known of the Asiatic forms; they are of much interest, and have been very little collected.

Insects.—Many of the most local and interesting insects of a country are not to be found without a knowledge of their habits, and some are nocturnal. In wooded and mountainous countries they must be searched for in dead wood, under logs, stones, fallen fruit, or moss, in folded leaves, on sandy river banks, and under shingle, about roots of herbage, in small dead vertebrated animals, &c., &c. The best way of forming a collection is to pin and set out the captures of each day before retiring to rest, and,

after drying them, to store the specimens in air-tight corked boxes. It is only thus that good museum specimens can be obtained, and the colours and fine hairy clothing with which many species are furnished preserved. But on a journey of exploration this is quite impracticable, and all travellers, including professional natural history collectors, now adopt more summary and compact methods; laying all the hard-bodied tribes in prepared sawdust, and folding all the delicate-winged species in small triangular paper envelopes. The former class should be collected in broad-mouthed bottles, containing a minute piece of cyanide of potassium, or in insect "killing bottles," as described in the foot-note at p. 398, it being necessary to kill them speedily, to prevent their mutilating each other and destroying their value as specimens. On reaching camp the contents should be shaken out (into boiling water if not already killed), and then placed in boxes, between layers of large-grained, or sifted and well-dried, sawdust. The under side of the lid of the box should be moistened with carbolic acid, which will prevent the attacks of insects or moisture, and the sawdust also sprinkled, but so as not to touch the specimens, the colours of which would be tarnished by the acid. When the box is filled the lid may be lightly nailed down, and it is then ready for transmission home. In collecting ants, it is necessary to open nests at the time of swarming, and to secure the winged individuals, as well as the wingless workers of various sizes, of each species, the whole set being kept together and duly labelled. To facilitate this, the set may be lightly gummed on cardboard before placing them in sawdust. The more delicate-winged insects, such as butterflies, moths, dragon-flies, &c., should be killed by pressing the breast underneath the wings with thumb and forefinger (taking great care not to injure the wings), and then dropping them with closed wings each into its paper envelope (a supply of which is to be taken on every excursion); on reaching camp the envelopes, thus filled each with its specimen, should be packed, without pressing them too tightly, in boxes. Spiders and crustacea, land and fresh-water, may be collected in bottles containing spirit, where they may remain; but spirits should not be used for any other class of insects, except in the case of specimens intended for dissection of the internal parts, as alcohol distorts the forms and destroys the colours and pubescence.

Mountain travellers will have many opportunities of obtaining valuable specimens of insects, but they cannot be expected to carry the usual

relatively bulky collecting apparatus. The poison-bottle must be small enough to go into the waistcoat pocket, and the traveller should be provided with a number of little "self-opening" tin boxes, ready filled with sawdust, and a particle of naphthalin. Each box should be reserved for the insects found on one day, or in one locality, and duly labelled outside and inside. It is impossible in the narrow limits of a mountaineer's tent, and with the little time at his disposal, to pack insects in layers in a larger box, or to make any of the arrangements which a professed naturalist is accustomed to.

Botanical Collecting. By the late J. BALL, F.R.S. — To obtain good specimens of dried plants in a condition serviceable to scientific men, the following are the chief points to be observed:—

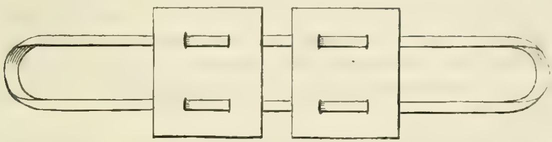
1. *Selection of Specimens.*—The object is to give as much information as possible respecting the plant which it is intended to collect. Small plants not exceeding 16 inches in height should be collected *entire with the roots.* Slender plants of greater dimensions may be folded to the same length, and may often be collected entire. Of larger plants, shrubs and trees, the object is to show as much as possible of the plant within the limit of the size of your drying paper. As an universal rule, both the flower and fruit (seed-vessel) should, if possible, be preserved. Of those plants whereon the male and female flowers grow separately, specimens of both should, if possible, be collected.

2. *Conveyance of Specimens to Camp or Station.*—Tin boxes made for the purpose are generally used in Europe for carrying botanical specimens until they can be placed in the drying press. They answer sufficiently well in cool weather, but in hot countries specimens are often partly withered before they can be laid out; and a rough portfolio, into which the plants can be put when (or soon after) they are gathered, is much to be preferred.

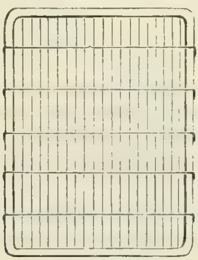
Such a portfolio is easily prepared with two sheets of millboard connected by an endless tape, so as to be easily slung over the shoulder; between these about thirty or forty sheets (60 to 80 folds) of thin soft (more or less bibulous) paper may be carried and kept in place by a strap or piece of twine. With two such portfolios a traveller can carry as many plants as it is possible to collect with advantage in a day. As soon as possible after being gathered, the specimens should be laid roughly between the sheets of paper: except in the case of delicate flowers, no

special care is needed, and no harm comes of two or three being put together.

3. *The Drying Press.*—The great object, both to secure good specimens and to save labour and weight of paper, is to get the plants dried quickly; and for this one of the first conditions is to lose as little time as possible. When practicable, the specimens should always be put in the press on



the same day on which they are gathered. The press should be made with two outer gratings of iron wire; the outer frame of strong wire, about a quarter of an inch in diameter—the size being that of the paper used. Between these the paper is laid. As to the choice of drying paper, the general rule is, that the coarser it is the better, provided it be quite or nearly quite free from size.

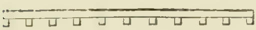


To enable the plants to dry quickly, the traveller should be provided with light wooden gratings of the same size as the drying paper. I think the size 18 inches × 12 inches is quite large enough. The iron wire outer gratings may with advantage be a quarter of an inch longer and broader to save the edges of the wooden gratings.

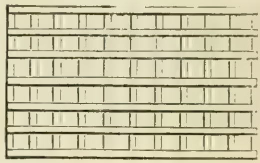
These should be made of light laths fastened with a few nails (all the

better if these are of copper), the interstices should be rather less than three-quarters of an inch, at all events not more. Their use is to allow the air to circulate through the pile of plants that are being dried. One should be inserted at each interval of about two inches (counting the drying paper and the plants laid out for drying), and when this is done the parcel may with advantage be exposed to the sun or placed near a fire, as the case may be. In dry warm climates, the majority of plants may be dried in the course of a few days, and will be fit to pack up, without any need of changing the drying paper in which they were originally placed; but in damp weather, and in regard to plants of thick fleshy foliage, it is usually necessary to change the paper more than once before the specimens are thoroughly dry.

The pile of paper, with plants between each five or six thicknesses of paper, and gratings at intervals of about two inches, should be squeezed



GRATING SEEN FROM THE EDGE.



GRATING SEEN FROM ABOVE.

between the outer (iron) gratings by means of two strong straps. Too much pressure is not desirable. For a pile ten or twelve inches thick, the parcel may be pulled nearly as tight as a moderate man can do it; but in proportion as the thickness is less, the pressure should be moderated.

Plants with fleshy leaves are very difficult to dry well. The best way is to dip them in water quite boiling for a minute or less, then to lay them between a few sheets of drying paper with slight pressure, merely to remove the exterior moisture, and then place them (when externally dry) in the drying press. Plants collected in rain should be treated in a similar way to remove outer moisture before it is attempted to dry them.

4. When once dry, plants may be packed away between paper of almost any kind. Old newspapers answer very well. The only precaution needed is to preserve them from insects.

The chief trouble in collecting plants is to get the paper already used thoroughly dry before it is again employed. The best resource in dry climates is to stretch cords and hang these papers exposed to sun and air. Artificial heat must be resorted to in wet seasons, but the process is then slow and troublesome.

For a traveller wishing to make large collections, the time consumed in changing the paper in which the plants are dried becomes an important consideration. I have adopted with advantage a suggestion of the late Professor A. Gray to use, instead of ordinary drying paper, sheets, cut to the proper size, of the paper-felt which is used for laying under carpets. The specimens when originally laid out for drying are placed within sheets of thin paper without size, such as filtering paper, and as a rule these do not need to be changed. One sheet of felt-paper is generally sufficient between each layer of plants, and the operation of changing the paper is very quickly effected.

It is an important rule to note the locality where the specimens have been collected, with the date. If proper care be taken to keep together all the specimens collected at the same time, it is not necessary to place a separate scrap of paper within each sheet; but it is advisable to do this when the dried specimens are packed for transmission home.

5. *Seeds.*—Travellers may easily make valuable contributions to our knowledge of the vegetation of distant countries by preserving seeds of remarkable and unusual plants. The only precautions necessary are, to select seeds that are fully ripe; if enclosed in a seed vessel, or covering of a succulent character, to take care that this is thoroughly dried before they are packed; and that they are preserved from moisture during the homeward voyage. Small seeds may be enclosed in paper, the larger kinds in canvas bags, and the whole wrapped in a piece of oiled cloth. It is very desirable to keep each description of seed separate, and to note the place where it was gathered, with indications of altitude, soil, and climate.

6. *Bulbs.*—These are easily obtained, but, as a rule, they should be taken only at the end of the growing season, and kept until the leaves are quite withered. They should be packed dry in a small box with shavings, or other elastic stuffing. The same treatment will suit the pseudo-bulbs of some orchids.

7. *Fleshy Tubers.*—These and thick rhizomes may best be sent in boxes,

wrapped in slightly moist materials, such as cocoa-nut fibre, peat, or leaf mould.

8. *Living Plants.*—As a general rule, these require to be established in pots or boxes for some time before being packed for transmission. They travel best in what are called Wardian cases; but an ordinary wooden box covered with a glass top, and with sufficient moisture in the soil and air to prevent excessive evaporation, is found to answer the purpose. The cases should be kept on deck under some protection from the direct heat of the sun. Tropical plants should be despatched so as to reach England during the summer months. At other seasons they are liable to perish from cold.

9. *Succulent Plants,* such as cacti, aloe, houseleeks, &c., survive for a long time if packed without earth in a perfectly dry box, with sufficient openings for ventilation.

10. Small plants with woody roots and cuttings of larger species of plants from the north or south temperate zones often travel successfully when merely packed with a little soil, slightly moist, about the roots, and a wrapping of damp moss, or similar substance, tied up in thick paper or canvas. There is, however, much risk of failure in these cases where, on the homeward voyage, it is necessary to pass through the tropics.

As a general rule, plants are more often injured by excess of moisture than by being sent too dry.

It is desirable to make use of every favourable opportunity for sending botanical collections of all kinds to England, as in hot countries they are always exposed to risk of injury.

It is scarcely necessary to mention that living plants, as well as seeds and bulbs, should be placed in the hands of skilful gardeners after reaching this country. The chance of preserving interesting specimens is commonly much greater when they are sent to botanic gardens than when entrusted to private cultivators. In all cases information as to the soil and climate of the native home of the plant is a necessary guide to proper treatment.

Fossils.—The collection of fossils and minerals (except in the case of the discovery of new localities for valuable metals) is not to be recommended to the traveller, if he is not a geologist. Fossils from an unexplored country are of little use unless the nature and order of superposition of the strata in which they are found can be at the same time

investigated. In the cases, however, of recent alluvial strata or the supposed beds of ancient lakes, or deposits in caves, or raised sea-beaches containing shells or bones of vertebrate animals, the traveller will do well to bring away specimens if a good opportunity offers. If the plan of the expedition includes the collection of fossil remains, the traveller will, of course, provide himself with a proper geological outfit, and obtain the necessary instructions before leaving Europe. (*See* Section VII.)

General Remarks.—All collections made in tropical countries should be sent to Europe with the least possible delay, as they soon become deteriorated and spoilt unless great care be bestowed upon them. Dry skins of animals and birds may be packed in wooden cases well lined and padded with brown paper. Shells and skulls should be provided with abundance of elastic padding, such as cotton. Boxes containing pinned insects and crustacea should be packed within larger boxes and surrounded by an ample bed of hay or other light dry elastic material; unless this last point is carefully attended to, it is doubtful whether such collections will sustain a voyage without more or less serious injury.

Observations of Habits, &c.—Travellers have excellent opportunities of observing the habits of animals in a state of nature, and these 'Hints' would be very deficient were not a few remarks made upon this subject. To know what to observe in the economy of animals is in itself an accomplishment which it would be unreasonable to expect the general traveller to possess, and without this he may bring home only insignificant details, contributing but little to our stock of real knowledge. One general rule, however, may be kept always present to the mind, and this is, that anything concerning animals which bears upon the relations of species to their conditions of life is well worth observing and recording. Thus, it is important to note the various enemies which each species has to contend with, not only at one epoch in its life, but at every stage from birth to death, and at different seasons and in different localities. The way in which the existence of enemies limits the range of a species should also be noticed. The inorganic influences which inimically affect species, especially intermittently (such as the occurrence of disastrous seasons), and which are likely to operate in limiting their ranges, are also important subjects of inquiry. The migrations of animals, and especially any facts about the irruption of species into districts previously uninhabited by them, are well worth recording. The food of each species

should be noticed, and if any change of customary food is observed, owing to the failure of the supply, it should be carefully recorded. The use in nature of any peculiar physical conformation of animals, the object of ornamentation, and so forth, should also be investigated whenever opportunity occurs. Any facts relating to the interbreeding in a state of nature of allied varieties, or the converse—that is, the antipathy to intercrossing of allied varieties—would be extremely interesting. In short, the traveller should bear in mind that facts having a philosophical bearing are much more important than mere anecdotes about animals.

To observe the actions of the larger animals, a telescope or opera-glass will be necessary. The traveller should bear in mind, if a microscope is needed in his journey, that by unscrewing the tubes of the telescope in which all the small glasses are contained, a compound microscope of considerable power may be produced.

IX.

ANTHROPOLOGY.

By E. B. Tylor, D.C.L., F.R.S.

The characters of men's bodies and minds being matters of common observation, Europeans not specially trained in anthropology, who have happened to be thrown among little-known tribes, often bring home valuable anthropological information. Though explorers, traders, and colonists have made their way into almost every corner of the earth, it is surprising to find how many new facts may still be noted down by any careful observer. If familiar with anthropological methods, he will, of course, observe more and better. The hints here given will serve to draw attention to interesting points which might otherwise be overlooked. Directions for such investigation, drawn up in much greater detail, will be found in the small British Association manual entitled: 'Notes and Queries on Anthropology' (Anthropological Institute, 3, Hanover Square, W.).

Physical Characters.—On first coming among an unfamiliar race, such as the Negroes, the traveller is apt to think them almost alike, till after a few days he learns to distinguish individuals more sharply. This first impression, however, has a value of its own, for what he vaguely perceived was the general type of the race, which he may afterwards gain a more perfect idea of by careful comparison. Among tribes who for many generations have led a simple uniform life and mixed little with strangers, the general likeness of build and feature is very close, as may be seen in a photograph of a party of Caribs or Andamaners, whose uniformity contrasts instructively with the individualised faces of a party of Europeans. The consequence is that a traveller among a rude people, if he has something of the artist's faculty of judging form, may select groups for photography which will fairly represent the type of a whole

tribe or nation. While such portrait-groups are admirable for giving the general idea of a race, characteristic features belonging to it should be treated separately. For instance, to do justice to the Tartar eye or the Australian forehead, the individual feature must be carefully sketched or photographed large.

How deceptive mere unmeasured impressions of size may be is shown by the well known example of the Patagonians, who, though really only tall men (averaging 5 feet 11 inches), long had the reputation of a race of giants. Such measurements as any traveller can take with a measuring-tape and a three-foot rule with sliding square are good if taken with proper precautions. As the object of the anthropologist is to get a general idea of a race, it may be in some respects misleading to measure at random one or two individuals, who are perhaps not fair specimens. If only a few can be measured, they should be selected of ordinary average build, full-grown but not aged. What is much better is to measure a large number (twenty to fifty) of persons taken indiscriminately as they come, and to record the measurements of each with sex, age, name, locality, &c. Such a table can afterwards be so classified as to show not only the average or mean size, but the proportion of persons who vary more or less from that mean size; in fact, it represents on a small scale the distribution of stature, &c., in the whole people. Gigantic or dwarfish individuals, if not deformed, are interesting as showing to what extremes the race may run. The most ordinary measurements are height, girth round chest, fathom or length of outstretched arms, length of arm from shoulder and leg from hip, length of hand and foot. The traveller may find that such measuring of another race shows very different stature and girth from that of his own companions, who, if they are well grown Europeans, may stand 5 feet 8 inches to 6 feet, and measure 34 to 36 inches round the chest. Beyond this, he will find that the relative proportions of parts of the body differ from those he is accustomed to. An example of this is seen by placing Europeans and negroes side by side, and noticing how much nearer the knee the negro's finger-tips will reach. It will be found that body measurement needs skill in taking the corresponding points, and in fact all but the simplest measures require some knowledge of anatomy. This is especially the case with skull measurements. There are instruments for taking the dimensions of the living head, and with care and practice the untrained observer may get at

some of the more conspicuous, such as the relative length and width of the skull as taken by hatters. This roughly indicates the marked difference between dolichokephalic or long-headed peoples, like the African negro, and brachykephalic or short-headed peoples, like the Kalmuks and other Tartars. Attention should be paid also to the degree of prognathism or projection of jaw, which, in some races, as the Australian, gives a "muzzle" unlike the English type. Where practicable, native skeletons, and especially skulls, should be sent home for accurate examination. How far this can be done depends much on the feeling of the people; for while some tribes do not object to the removal of bones, especially if not of their own kinsfolk, in other districts it is hardly safe to risk the displeasure of the natives at the removal of the dead—a feeling which is not only due to affection or respect, but even more to terror of the vengeance of the ghosts whose relics have been disturbed.

In describing complexion, such terms as "brown" or "olive," so often used without further definition in books of travel, are too inexact to be of use. Broca's scale of colours (see the Anthropological 'Notes and Queries') gives means of matching the tints of skin, hair, and eyes; if this is not forthcoming, the paint-box should be used to record them. Among rude tribes, the colour of the skin is often so masked by paint and dirt that the subject must be washed to see the real complexion. Hair is also an important race-mark, varying as it does in colour from flaxen to black, and also in form and size of the hairs; for instance the American Indian's coarse straight hair seems almost like a horse's tail in comparison with the Bushman's hair with its natural frizz of tiny spirals. Locks of hair should therefore be collected. The traveller, however, will often find some difficulty in getting such specimens, from the objection prevalent in the uncivilised world of letting any part of the body, such as hair and nail-clippings, pass into strangers' hands lest they should be used to bewitch their former owner. Even in such countries as Italy, to ask for a lock of a peasant-girl's hair may lead to the anthropologist being suspected of wishing to practise love-charms on her.

Differences of temperament between nations are commonly to be noticed; for instance, in comparing the shy and grave Malays with the boisterous Africans. It is an interesting but difficult problem how far such differences are due to inherited race-character, and how far to such social influences as education and custom, and to the conditions of life

being cheerful or depressing. Nor has it yet been determined how far emotions are differently expressed by different races, so that it is worth while to notice particularly if their smiling, laughing, frowning, weeping, blushing, &c., differ perceptibly from ours. The acuteness of the senses of sight, hearing, and smell, among wild peoples is often remarkable, but this subject is one on which many accounts have been given which require sifting. The skill of savages in path-finding and tracking depends in great measure on this being one of their most necessary arts of life, to which they are trained from childhood, as, in an inferior degree, gipsies are with us. The native hunter or guide's methods of following the track of an animal, or finding his own way home by slight signs, such as bent twigs, and keeping general direction through the forest by the sky and the sheltered sides of the trees, are very interesting, though when learnt they lose much of their marvellous appearance. The testing of the mental powers of various races is an interesting research, for which good opportunities now and then occur. It is established that some races are inferior to others in volume and complexity of brain, Australians and Africans being in this respect below Europeans, and the question is to determine what differences of mind may correspond. Setting aside the contemptuous notions of uneducated Europeans as to the minds of "black-fellows" or "niggers," what is required is, to compare the capacity of two races under similar circumstances. This is made difficult by the fact of different training. For instance, it would not be fair to compare the European sportsman's skill in woodcraft and hunting with that of the native hunter, who has done nothing else since childhood; while, on the other hand, the European, who has always lived among civilised people, owes to his education so much of his superior reasoning powers, that it is mostly impossible to get his mind into comparison with a savage's. One of the best tests is the progress made by native and European children in colonial or missionary schools, as to which it is commonly stated that children of African or American tribes learn as fast as or faster than European children up to about twelve, but then fall behind. Even here it is evident that other causes besides mental power may be at work, among them the discouragement of the native children when they become aware of their social inferiority. The subject is one of great importance, both scientifically and as bearing on practical government.

Both as a matter of anthropology and of practical politics, the suitability of particular races to particular climates is of great interest; sometimes this depends on one race being free from a disease from which another suffers, as in the well-known immunity of negroes from yellow fever. Or it may be evident that tribes have become acclimatised, so as to resist influences which are deadly to strangers; for instance, the Khonds flourish in the hills of Orissa, where not only Europeans but the Hindus of the plains sicken of the malaria in the unhealthy season. That such peculiarities of constitution are inherited and pass into the nature of the race, is one of the keys to the obscure problem of the origins of the various races of man as connected with their spread over the globe. As yet this problem has not passed much beyond the stage of collecting information, and no pains should be spared to get at facts thus bearing on the history and development of the human species. European medical men in districts inhabited by uncivilised races have often made important observations of this kind, which they are glad to communicate, though being occupied with professional work they do not follow them up. In all races there occur abnormal varieties, which should be observed with reference to their being hereditary, such as Albinos, whose dead-whiteness is due to absence of pigment from the skin. Even such tendencies as that to the occurrence of red hair where the ordinary hue is black, or to melanism or diseased darkening of the skin, are worth remark. It is essential to discover how far these descend from parents to children, which is not the case with such alterations as that of the Chinese feet, which, in spite of generations of cramping, continue of the natural shape in the children.

Language.—Before coming to actual language, remark may be made on the natural communication of all races carried on by pantomimic signs without spoken words. This is the "gesture language" to which we are accustomed among the deaf-and-dumb, and which sometimes also comes into practical use between tribes ignorant of one another's languages, as on the American prairies. It is so far the same in principle everywhere, that the explorer visiting a new tribe, having to make frequent use of signs to supplement his interpreter, or to eke out his own scanty knowledge of the native language, soon adapts himself to the particular signs in vogue. He will observe that, as to most common signs, such as asking for food or drink, or beckoning or warning off a stranger, he understands

and is understood quite naturally. Signs which are puzzling at first sight will prove on examination to be intelligible. Some are imitative gestures cut short to save trouble, or they may have a meaning which was once evident, like the American Indian sign for dog, made by trailing two forked fingers, which does not show its meaning now, but did so in past times, when one principal occupation of the dog was to trail a pair of tent-poles fastened on his back. Besides its practical use, the gesture-language has much scientific interest from the perfect way in which it exposes the working of the human mind, expressing itself by a series of steps which are all intelligible. It will be particularly observed that it has a strict syntax; for instance, that the quality or adjective must always follow the subject or substantive it is applied to. Thus, "the white box" may be expressed by imitating the shape and opening of a box, and then touching a piece of linen or paper to show its colour; but if the signs be put in the contrary order, as in the English words, the native will be perplexed. It is worth while, in countries where gesture-language is regularly used, to note down the usual signs and their exact order

In recording a vocabulary of a language not yet reduced to form in a grammar and dictionary, the traveller may seek for equivalents of the principal classes of words in his own grammar: verbs, substantives, adjectives, pronouns, prepositions, &c. But the structure of the language he is examining will probably differ from any he is familiar with, the words actually used not coming precisely into these classes. The best method is for the traveller to learn a simple sentence, such as, "the men are coming," and to ascertain what changes will convert them into "the men are going," "the women are coming." He thus arrives at the real elements of the language and the method of combining them. Having arrived at this point, he will be able to collect and classify current ideas, such as the following:—

Actions—as stand, walk, sleep, eat, see, make, &c.

Natural Objects and Elements—as sun, moon, star, mountain, river, fire, water, &c.

Man and other Animals—as man, woman, boy, girl, deer, buck, doe, eagle, eagles, &c.

Parts of Body—as head, arm, leg, skin, bone, blood, &c.

Trees and Plants.

Numerals (noticing how far they extend, and whether referring to fingers).

Instruments and Appliances—as spear, bow, hatchet, needle, pot, boat, cord, house, roof, &c.

Arts and Pastimes—as picture, paint, carving, statue, song, dance, toy, game, riddle, &c.

Family Relationships (as defined by native custom).

Social and Legal Terms—as chief, freeman, slave, witness, punishment, fine, &c.

Religious Terms—as soul, spirit, dream, vision, sacrifice, penance, &c.

Moral Terms—as truth, falsehood, kindness, treachery, love, &c.

Abstract Terms, relating to time, space, colour, shape, power, cause, &c.

The interjections used in any language can be noted, whether they are organic expressions of emotion, like *oh! ugh! ur-r-r!* or sounds the nature of which is not so evident. Also imitative words which name animals from their cries, or express sounding objects or actions by their sounds, are common in all languages, and strike the stranger. Examples of such are *kah-kah* for a crow, *twonk* for a frog, *pututu* for a shell-trumpet, *haitschu* for to sneeze. When such imitative words are noticed passing into other meanings where the connection with sound is not obvious, they become interesting facts in the development of language; as, to take a familiar example from English, the imitative verb to *puff* becomes a term for light pastry and metaphorically blown-up praise.

It is only when the traveller has a long or close acquaintance with a tribe, that he is able to deal satisfactorily with the vocabulary and structure of their language. To be able to carry on a conversation in broken sentences is not enough, for an actual grammar and dictionary is required to enable philologists to make out the structure and affinities with other languages. It used to be customary to send out English lists of thirty or forty ordinary words to have equivalents put to them in native languages. As every detail of this kind is worth having, these lists cannot be said to be quite worthless, but they go hardly any way toward what is really wanted. They are liable to frequent mistakes, as when the barbarian, from whom the white man is trying to get the term "foot," answers with a word meaning "my leg," which is carefully taken down

and printed. Such poor vocabularies cannot even be relied on to show whether a language belongs to a particular family, for the very word which seems to prove this may be borrowed. Thus, in various African vocabularies, there appears the word *sapun* (or something similar) with the meaning of *soap;* but this is a Latin word which has spread far and wide from one country to another, and proves nothing as to original connexion between languages which have adopted it. While it is best not to under-rate the difficulty of collecting such information as to a little-known dialect as will be really of service to philology, it must be remembered that travellers still often have opportunities of preserving relics of languages, or at any rate special dialects, which are on the point of dying out unrecorded. Where no proper grammar and dictionary has been compiled, it is often possible to find some European or some interpreter fairly conversant with the language, with whose aid a vocabulary may be written out and sentences analysed grammatically, which, when read over to intelligent natives and criticised by them, may be worked into good linguistic material. It is worth while to pay attention to native names of plants, minerals, &c., as well as of places and persons, for these are often terms carrying significant meaning. Thus *ipecacuanha* is stated by Martius to be *i-pe-caa-guéne,* which in the Tupi language of Brazil, signifies "the little wayside plant which makes vomit."

Arts and Sciences.—The less civilised a nation is, the ruder are their tools and contrivances; but these are often worked with curious skill in getting excellent results with the roughest means. Stone implements have now been so supplanted by iron that they are not easily found in actual use. If a chance of seeing them occurs, as, for instance, among some Californian tribe, who still chip out arrow-heads of obsidian, it is well to get a lesson in the curious and difficult art of stone-implement making. In general, tools and implements differing from those of the civilised world, even down to the pointed stick for root-digging and planting, are worth collecting, and to learn their use from a skilled hand often brings into view remarkable peculiarities. This is the case with many cudgel- or boomerang-like weapons thrown at game, slings or spear-throwers for hurling darts to greater distances than they can be sent by hand, blow-tubes for killing birds, and even the bow-and-arrow, which in northern Asia and America shows the ancient Scythian or Tartar form, having to be bent inside out to string it. Though fire is now practically

made almost everywhere with flint and steel or lucifers, in some districts, as South Africa or Polynesia, people still know the primitive method of fire-making by rubbing or drilling a pointed stick into another piece of wood. Europeans find difficulty in learning this old art, which requires some knack. As is well known to sportsmen, different districts have their special devices for netting, trapping and other ways of taking game and fish, some of which are well worth notice, such as spearing or shooting fish under water, artificial decoys, and the spring-traps set with bent boughs, which are supposed to have first suggested the idea of the bow. While the use of dogs in hunting is found in most parts of the world, there is the utmost variety of breeds and training. Agriculture in its lower stages is carried on by simple processes; but interesting questions arise as to the origin of its grain and fruits, and the alterations in them by transplanting into a new climate and by ages of cultivation. Thus in Chili there is found wild what botanists consider the original potato; but while maize was a staple of both Americas at the time of Colombus, its original form has no more been identified than that of wheat in the Old World. The cookery of all nations is in principle known to the civilised European; but there are special preparations to notice, such as bucaning or drying meat on a hurdle above a slow fire, broiling kibabs or morsels of meat on the skewer in the East, &c. Many peoples have something peculiar in the way of beverages, such as the chewed Polynesian *kava*, or the South American *maté* sucked through a tube. Especially fermented liquors have great variety, such as the *kumiss* from mare's milk in Tartary, the *pombe* or millet-beer of Africa, and the *kvass* or rye-beer of Russia. The rudest pottery made by hand, not thrown on the wheel, is less and less often met with, but ornamentation traceable to its being moulded on baskets is to be seen; and calabashes, joints of bamboo, and close-plaited baskets, are used for water-vessels, and even to boil in. Among the curious processes of metal-working, contrasting with those of modern Europe, though often showing skill of their own, may be mentioned the simple African smelting-forge by which iron-ore is reduced with charcoal in a hole in the ground, the draught being supplied by a pair of skins for bellows. In the far East a kind of air-pump is used, of which the barrels are hollowed logs. The Chinese art of patching cast-iron with melted metal surprises a European, and the Hindu manufacture of native steel (*wootz*) is a remarkable process. No

nation now exists absolutely in the Bronze Age, but this alloy still occupies something in its old place in Oriental industry. As an example of the methods still to be seen, may be mentioned the Burmese bell-founding, which is done, not in a hollow mould of sand, but by what in Europe is called the *cire perdue* process, the model of the bell being made in bees-wax and imbedded in the sand-mould, the wax being melted and the hot metal taking its place. The whole history of machinery is open to the traveller, who still meets with every stage of its development, from savagery upward. He sees, for instance, every tilling implement from the stake with fire-hardened point, and the hoe of crooked branch, up to the modern forms of plough. In like manner he can trace the line from the rudest stone-crushers or rubbers for grinding seed or grain up to the rotating hand-mills or querns still common in the East, and surviving even in Scotland. From time to time some special contrivance may be seen near its original home, as in South America the curious plaited tube for wringing out the juice from cassava, or the net hammock which still retains its native Haitian name *hamaca*. Architecture still preserves in different regions interesting early stages of development, from the rudest breakwinds, or beehive huts of wattled boughs, up to houses of logs and hewn timber, structures of mud and adobes, and masonry of rough or hewn stone. Even the construction of the bough-hut or the log-house often has its peculiarities in the arrangements of posts and rafters. Among the modes of construction which interest the student of architectural history is building with rough unhewn stones. Many examples of "rude stone monuments" are to be seen on our own moors and hills. The most familiar kinds are *dolmens* (*i.e.* "table-stones"), formed by upright stones bearing a cap-stone; they were burial-places, and analogous to the cists or chambers of rough slabs within burial-mounds. Less clearly explicable are the single standing-stones or *menhirs* (*i.e.* "long-stones"), and the circles of stones or *cromlechs*. Ancient and obscure in meaning as such monuments are in Europe, there are regions where their construction or use comes down to modern times, especially in India, where among certain tribes the deposit of ashes of the dead in dolmens, the erection of menhirs in memory of great men, and even sacrifice in stone circles, are well-known customs. The traveller may also sometimes have opportunities of observing the ancient architectural construction by fitting together many-sided stones into what are some-

times called Cyclopean walls, a kind of building which seems to have preceded the use of squared blocks, fastened together with clamps or with mortar. Vaulting or roofing by means of courses of stones projecting inwards one course above the other (much as children build with their wooden bricks), so as to form what architects call a "false arch," is an ancient mode of construction found in various parts of the world where the "true arch" with its keystone has not superseded it. It often appears that rude nations have copied the more artistic buildings of higher neighbours, or inherited ancient architectural traditions. Thus traces of Indian architecture have found their way into the islands of the Eastern Archipelago, and hollow squares of mud-built houses round a courtyard in northern Africa have their plan from the Asiatic caravanserai. In boat-building some primitive forms, as the "dug-out," hollowed by the aid of fire from a tree-trunk, and the bark-canoe, are found in such distant regions that we cannot guess where they had their origin. When, however, it comes to the outrigger-canoe, this belongs to a district which, though very large, is still limited, so that we may at least guess whereabouts it first came into use, and it is important to note every island to which it has since travelled. So there is much in the peculiar build and rig of Malay prahus, Chinese junks, &c., which is worth noting as part of the history of ship-building. This may suffice to give a general idea of the kind of information as to the local arts which it is worth while to collect, and to illustrate by drawings and photographs of objects too large to bring away,

Naturally, nations below the upper levels of culture have little or no science to teach us, but many of their ideas are interesting as marking stages in the history of the human mind. Thus, in the art of counting, which is one of the foundations of science, it is common to find the primitive method of counting by fingers and toes still in practical use, while in many languages the numeral words have evidently grown up out of such a state of things. Thus *lima*, the well-known Polynesian word for five, meant "hand," before it passed into a numeral. All devices for counting are worth notice, from the African little sticks for units and larger sticks for tens, up to the ball-frames with which the Chinese and Russian traders reckon so rapidly and correctly. It is a sign of lowness in a tribe not to use measures and weights, and where these appear in a rough way, it is interesting to discover whether vague lengths, such as

finger, foot, pace, are used, or whether standard measures and weights have come in. If so, these should be estimated according to our standards with as much accuracy as possible, as it may thus become possible to ascertain their history. In connection with this comes the question of money; as to whether commerce is still in the rudimentary stage of exchanging gifts, or has passed into regular barter, or risen to regular trade, with some sort of money to represent value, even if the circulating medium be only cowries, or bits of iron, or cakes of salt, all which are current money to this day in parts of Africa. Outside the present higher civilisation, more or less primitive ideas of astronomy and geography will be found to prevail. Among tribes like the American Indians the obvious view suggested by the senses still prevails, that the earth is a flat round disc (or sometimes square, with four quarters or winds) overarched by a solid dome or firmament, on which the sun and moon travel—in inland countries going in and out at holes or doors on the horizon, or, if the sea bounds the view, rising from and plunging into its waves at sunrise and sunset. These early notions are to us very instructive, as they enable us to realise the conceptions of the universe which have come down to us in the ancient books of the world, but which scientific education has uprooted from our own minds. With these cosmic ideas are found among the lowest races the two natural periods of time, namely, the lunar month and the solar year, determined by recurring winters, summers, or rainy seasons. Such tribes divide the day roughly by the sun's height in the sky, but among peoples civilised enough to have time-measures and the sun-dial, there is a tolerably accurate knowledge of the sun's place at the longest and shortest days, and, indeed, throughout the year. The astronomy of such countries as India has been of course described by professional astronomers; but among ruder nations there is still a great deal unrecorded—for instance, as to the constellations into which they map out the heavens. This likening stars and star-groups to animals and other objects is almost universal among mankind. Savages like the Australians still make fanciful stories about them, as that Castor and Pollux are two native hunters, who pursue the kangaroo (Capella) and kill him at the beginning of the hot season. Such stories enable us to understand the myths of the Classical Dictionary, while modern astronomers keep up the old constellations as a convenient mode of mapping out the sky. As to maps of the earth, even low tribes have some notion of their principle,

and can roughly draw the chart of their own district, which they should be encouraged to do. Native knowledge of natural history differs from much of their rude science in its quality, often being of great positive value. The savage or barbarian hunter knows the animals of his own region and their habits with remarkable accuracy, and inherited experience has taught him that certain plants have industrial and medicinal uses. Thus, in South America the Europeans learnt the use of India-rubber or caoutchouc, which the native tribes were accustomed to make into vessels and playing-balls, and of the Peruvian bark or cinchona, which was already given to patients in fever.

Here a few words may be said of magic, which, though so utterly futile in practice, is a sort of early and unsuccessful attempt at science. It is easy, on looking into the proceedings of the magician, to see that many of them are merely attempts to work by false analogy or deceptive association of ideas. The attempt to hurt or kill a person by cutting or piercing a rude picture or image representing him, which is met with in all the four quarters of the globe, is a perfect example of the way in which sorcerers mistake mere association of ideas for real cause and effect. Examined from this point of view, it will be found that a large proportion of the magic rites of the world will explain their own meaning. It is true that this is not the only principle at work in the magician's mind; for instance, he seems to reason in a loose way that any extraordinary thing will produce any extraordinary effect, so that the peculiar stones and bits of wood which we should call curiosities become to the African sorcerer powerful fetishes. It will often be noticed that arts belonging to the systematic magic of the civilised world, which has its source in Babylon and Egypt, have found their way into distant lands more readily indeed than useful knowledge, so that they may even be met with among barbaric tribes. Thus it has lately been pointed out that the system of lucky and unlucky days, which led the natives in Madagascar to kill many infants as of inauspicious birth, is adopted from Arabic magic, and it is to be expected that many other magical arts, if their formulas are accurately described, may in like manner be traced to their origin.

Society.—One of the most interesting features of savage and barbaric life is the existence of an unwritten code of moral conduct, by which families and tribes are practically held together. There may be no laws

to punish crime, and the local religion may no more concern itself directly with men's behaviour to one another than it did in the South Sea Islands. But among the roughest people there is family affection, and some degree of mutual help and trust, without which, indeed, it is obvious that society would break up, perhaps in general slaughter. Considering the importance of this primitive morality in the history of mankind, it is unfortunate that the attention of travellers has been so little drawn to it, that our information is most meagre as to how far family affection among rude tribes may be taken to be instinctive, like that of the lower animals, or how far morality is produced by public opinion favouring such conduct as is for the public good, but blaming acts which do harm to the tribe. It is desirable to inquire what conduct is sanctioned by custom among any people, whether, for instance, infanticide is thought right or wrong, what freedom of behaviour is approved in youths and girls, and so on. For though breaches of custom may not be actually punishable, experience will soon convince any explorer among any rude tribe that custom acts in regulating their life even more strictly than among ourselves. The notion of even savages leading a free and unrestrained life is contradicted by those who know them best; in fact, they are bound in every act by ancestral custom. While each tribe thus has its moral standard of right and wrong, this differs much in different tribes, and one must become intimately acquainted with any people to ascertain what are really their ruling principles of life. Accounts have been often given of the natural virtue and happiness of rude tribes, as in the forests of Guiana or the hills of Bengal, where the simple native life is marked by truthfulness, honesty, cheerfulness, and kindness, which contrast in a striking way with the habits of low-class Europeans. There are few phenomena in the world more instructive than morality thus existing in practical independence either of law or religion. It may still be possible to observe it for a few years before it is altered by contact with civilisation, which, whether it raises or lowers on the whole the native level, must supersede in great measure this simple family morality.

The unit of social life is the family, and the family is based on a marriage-law. Travellers who have not looked carefully into the social rules of tribes they were describing, or whose experience has been of tribes in a state of decay, have sometimes reported that marriage hardly existed. But this state of things is not confirmed as descriptive of any

healthy human society, however rude; in fact, the absence of definite marriage appears incompatible with the continued existence of a tribe. Therefore statements of this kind made by former visitors should be carefully sifted, and marriage-laws in general deserve careful study. The explorer will hardly meet with marriage at so low a stage that the union can be described as little beyond annual pairing; but where divorce is almost unrestricted, as in some African tribes, there is more or less approach to this condition, which is possible, though unusual, under such laws as that of Islam. Polygamy, which exists over a large part of the globe, is a well-understood system, but information is less complete as to the reasons which have here and there led to its opposite, polyandry, as among the Toda hill-tribes and the Nairs in South India. Among customs deserving inquiry are match-making festivals at spring-tide or harvest, when a great part of the year's marriages are arranged. This is not only often done among the lower races, but traces of it remain in Greece, where the dances at Megara on Easter Tuesday are renowned for wife-choosing, and till lately in Brittany, where on Michaelmas Day the girls sate in a row decked in all their finery on the bridge of Penzé, near Morlaix. The custom of bride-capture, where the bridegroom and his friends make show of carrying off the bride by violence, is known in Europe as a relic of antiquity, as in ancient Rome, Wales within the last century or two, or Tyrol at the present day; but in more barbaric regions, as on the Malay peninsula or among the Kalmuks of North Asia, it may be often met with, practised as a ceremony, or even done in earnest. On the other hand, restrictions on marriage between kinsfolk or clansfolk are more prominent among the lower races than in the civilised world, but their motive is even now imperfectly understood. Partly these restrictions take the form we are accustomed to of prohibiting marriage between relatives more or less near in our sense, but among nations at a lower level they are apt to involve also what is called exogamy or "marrying-out." A tribe or people—for instance, the Kamilaroi of Australia, or the Iroquois of North America—is divided into hereditary clans, members of which may not marry in their own clan. In various parts of the world these clans are named from some animal, plant, or other object, and anthropologists often call such names "totems," this word being taken from the native name among Algonquin tribes of North America. For an instance of the working of this custom among the Iroquois tribes,

a Wolf was considered brother to a Wolf of any other tribe, and might not marry a Wolf girl, who was considered as his sister, but he might marry a Deer or a Heron. In contrast with such rules is the practice of endogamy, or "marrying-in," as among the Arab tribes, who habitually marry cousins. But it will be found that the two rules often go together, as where a Hindu must practically marry within his own caste, but at the same time is prohibited from marrying in his own gotra or clan. Researches into totem-laws are apt to bring the traveller into contact with other relics of the ancient social institutions in which these laws are rooted, especially the practice of reckoning descent not on the father's side, as with us, but on the mother's side, after the manner of the Lycians, whose custom seemed extraordinary to the Greeks in the time of Herodotus, but may be still seen in existence among native tribes of America or in the Malay islands. Even the system of relationship familiar to Europeans is far different from those of regions where forms of the "classificatory system" prevail, in which father's brothers and mother's sisters are called fathers and mothers. In inquiring into native laws of marriage and descent, precautions must be taken to ensure accuracy, and especially such ambiguous English words as "uncle" or "cousin" should be kept clear of.

Another point on which travellers have great opportunity of seeing with their own eyes the working of primitive society is the holding and inheritance of property, especially land. Notions derived from our modern law of landlord and tenant give place in the traveller's mind to older conceptions, among which individual property in land is hardly found. In rude society it is very generally the tribe which owns a district as common land, where all may hunt and pasture and cut fire-wood; while, when a family have built a hut, and tilled a patch of land round it, this is held in common by the family while they live there, but falls back into tribe-land if they cease to occupy it. This is further organised in what are now often called "village communities," which may be seen in operation in Russia and India, where the village fields are portioned out among the villagers. Those who have seen them can understand the many traces in England of the former prevalence of this system in "common fields," &c. There is the more practical interest in studying the working of this old-world system from the light it throws on projects of communistic division of land, which in such villages may be studied,

and its merits and defects balanced. On the one hand it assures a maintenance for all, while on the other it limits the population of a district, the more so from the obstinate resistance which the council of "old men" who manage a village always oppose to any improved method of tillage. Not less perfectly do the tenures existing in many countries show the various stages of landholding which arise out of military conquest. The absolute ownership of all the land by a barbaric chief or king, which may be seen in such a country as Dahome, whose subjects hold their lands on royal sufferance, is an extreme case. In the East, feudal tenures of land granted for military service still have much the same results as in mediæval Europe.

At low levels of civilisation the first dawning of criminal law may be seen in the rule of vengeance or retaliation. The person aggrieved, or his kinsfolk if he has been killed, are at once judges and executioners, and the vengeance they inflict stands in some reasonable relation to the offence committed. Not only is such vengeance the great means of keeping order among such rude tribes as the Australians, but even among half-civilised nations like Abyssinians and Afghans the primitive law may still be studied in force, carried out in strict legal order as a *lex talionis*, not degraded to mere illegal survival in outlying districts like the "vendetta" of modern Europe, carried on even now, in spite of criminal jurisprudence, which for ages has striven to transfer punishment from private hands to the State. Whether among savages, barbarians, or the lower civilised nations, the traveller will find everywhere matter of interesting observation in the law and its administration. The law may be still in the state of unwritten custom, and the senate or council of old men may be the judges, or the power at once of lawgiver and judge may have passed into the hands of the chief, who, as among the modern Kafirs, may make a handsome revenue by the cattle given him as fees by both sides, a fact interesting as illustrating the times when an European judge took gifts as a matter of course. Among the nations at higher levels of culture in the East, for instance, most of the stages may still be seen through which the administration of law, criminal and civil, was given over to a trained legal class. One important stage in history is marked by religion taking to itself legal control over the conduct of a nation. The working of this is seen among Oriental nations, whether Mohammedan, Brahman, or Buddhist, whose codes of law are of an ecclesiastical type, and the

lawyers theologians. There is much to be learnt from the manner in which such law is administered, and the devices are interesting by which codes framed under past conditions of society are practically accommodated to a new order of things, without professedly violating laws held to be sacred, and therefore unchangeable. Ordeals, which have now disappeared from legal procedure among European nations, are often to be met with elsewhere. Thus in Arabia the ordeal by touching or licking hot iron is still known (the latter is an easy and harmless trick, if the iron is quite white-hot). In Burma, under native rule, the ancient trial of witches by "swimming" went on till lately. In many countries also symbolic oaths invoking evils on the perjurer are to be met with, as when the Ostyaks in Siberia swear in court by laying their hand on a bear's head, meaning that a bear will kill them if they lie. It shows the carelessness with which Europeans are apt to regard the customs of other nations, that in English courts a Chinese is called upon to swear by breaking a saucer, under the entirely erroneous belief that this symbolic curse is a Chinese judicial oath.

The most undeveloped forms of government are only to be met with in a few outlying regions, as among some of the lower Esquimaux or Rocky Mountain tribes, where life goes on with hardly any rule beyond such control as the strong man may have over his own household. Much oftener travellers have opportunity of studying, in a more or less crude state, the types of government which prevail in higher culture. It is of especial interest to see men of the whole tribe gathered in assembly (the primitive *agora*) to decide some question of war or migration. Not less instructive are the proceedings of the council of old men (the primitive *senate*), who, among American tribes or the hill tribes of India, transact the business of the tribe; they are represented at a later social stage by the village-elders of the Hindus or the Russians. Among the problems which present themselves among nations below the civilised level is that of the working of the patriarchal system, still prevailing among such tribes as the Bedaween, while often the balance of power is seen adjusting itself between the patriarchal heads of families and the leaders who obtain authority by success in war. The struggle between the hereditary chief or king and the military despot, who not only usurps his place but seeks to establish hereditary monarchy in his own line, is one met with from low to high levels of national life. The traveller's attention may be

called to the social forces which do their work independently of men in authority, and make society possible, even when there is little visible authority at all. The machinery of government described in books is often much less really powerful than public opinion, which controls men's conduct in ways which are so much less conspicuous that they have hardly yet been investigated with the care they deserve.

Religion and Mythology.—While great religions, like Mohammedanism and Buddhism, have been so carefully examined that European students often know more about their sacred books than the believers themselves, yet the general investigation of the religions of the world is very imperfect, and every effort should be made to save the details from being lost as one tribe after another disappears, or passes into a new belief. Missionaries have done much in recording particulars of native religions, and some have had the skill to describe them scientifically; but the point of view of the missionary engaged in conversion to another faith is unfavourable for seeing the reasons of the beliefs and practices he is striving to upset. The object of the anthropologist is neither to attack nor defend the doctrines of the religion he is examining, but to trace their rational origin and development. It is not only among the rudest tribes that religious ideas which seem of a primitive order may be met with, but these hold their place also among the higher nations who profess a "book-religion." Thus the English or German peasant retains many ideas belonging to the ancestral religion of Thor and Woden, and the modern Burmese, though a Buddhist, carries on much of the old worship of the spirits of the house and the forest, which belong to a far earlier religious stratum than Buddhism. It is in many districts possible for the traveller to obtain at first hand interesting information as to the philosophical ideas which underlie all religions. All over the world, people may be met with whose conception of soul or spirit is that belonging to primitive animism, namely, that the life or soul of men, beasts, or things, resides in the phantoms of them seen in dreams and visions. Quite lately, a traveller in British Guiana had serious trouble with one of his Arawaks, who, having dreamt that another had spoken impudently to him, on waking up went quite naturally to his master to get the offender punished. So it is reported that our officials in Burma have considered themselves disrespectfully treated when the wife or servant of the person they have come to see has refused to wake him, the

Englishman not understanding that these people hold early animistic ideas, believing the soul to be away from the sleeper's body in a dream, so that it might not find its way back if he were disturbed. As scientific ideas of the nature of life and dreams are rapidly destroying these primitive conceptions, it is desirable to collect all information about them for its important bearing on the history of philosophy and religion. The same may be said as to the ancient theory of diseases as caused by demons, and the expulsion and exorcism of them as a means of cure, which may still be studied everywhere outside the scientific nations. Information as to religious rites is of course valuable, even when the foreign observer does not understand them, but if possible their exact meaning should be made out by some one acquainted with the language, otherwise acts may be confused which have really different senses, as where a morsel of food offered as a pious offering to an ancestral ghost may be taken for a sacrifice to appease an angry wood-demon. A people's idea as to the meaning of their own rites may often be very wrong, but it is always worth while to hear what they think of the purpose of their prayers, sacrifices, purifications, fasts, feasts, and other religious ordinances, which even among savage tribes have been long since stereotyped into traditional systems.

Mythology is intimately mixed up with religion, which not only ascribes the events of the world to the action of spirits, demons, or gods, but everywhere individualises many of these beings under personal names, and receives as sacred tradition wonder-tales about them. Thus, to understand the religion of some tribes, we have not only to consider the rude philosophy under which such objects as heaven and earth or sun and moon are regarded as personal beings, whose souls (so to speak) are the heaven-god and earth-god, the sun-god and moon-god; but we have to go on further and collect the religious myths which have grown on to these superhuman beings. The tales which such a people tell of their origin and past history may to some extent include traditions of real events, but mostly they consist of myths, which are also worth collecting, as they often on examination disclose their origin, or part of it. This is seen, for instance, in the South Sea Island tale of the god Maui, whose death, when he plunged into the body of his great ancestress the Night, is an obvious myth of the sunset. The best advice as to native mythology is to write down all promising native stories, leaving it to future examination to

decide which are worth publishing. The native names of personages occurring in such stories should be inquired into, as they sometimes carry in themselves the explanation of the story itself, like the name of Great-Woman-Night in the Polynesian myth just referred to. Riddles are sometimes interesting, as being myths with an explanation attached, like the Greek riddle of the twelve black and twelve white horses that draw the chariot of the day. It is not too much to say that everything which a people thinks worth remembering as a popular tradition, and all the more if it is fixed in rhyme or verse, is worth notice, as likely to contain something of historical value. That it may not be historically true is beside the question, for the poetic fictions of a tribe often throw more light on their history than their recollections of petty chiefs who quarrelled fifty years ago. The myths may record some old custom or keep up some old word that has died out of ordinary talk, or the very fact of their containing a story known elsewhere in the world may give a clue to forgotten intercourse by which it was learnt.

Customs.—It remains to say a few words as to the multifarious customs which will come under the traveller's observation. It does not follow that because these may be mentioned or described in books they need not be further looked into. The fact is that accurate examination in such matters is so new, that something always remains to be made out especially as the motives of so many customs are still obscure. The practice of artificially deforming the infant's skull into a desired shape, which is not quite forgotten even in Europe, may be noticed with respect to the question whether the form to which the child's head is bulged or flattened is the exaggeration of the natural form of an admired caste or race. If not, what can, for instance, have induced two British Columbian tribes, one to flatten their foreheads and the other to mould them up to a peak? In tattooing, an even more widespread practice, it is well to ascertain whether the pattern on the skin seems to have been originally tribe-marks or other signs or records, or whether the purpose is ornament. In South-east Asia the two motives are present at once, when a man has ornamental designs and magical charm-figures together on his body. With regard to ornaments and costumes, the keeping-up of ancient patterns for ceremonial purposes often affords curious historical hints. Thus in the Eastern Archipelago, the old-fashioned garments of bark-cloth are used in mourning by people who have long discarded them in ordinary wear,

and another case is found among some natives of South India, whose women, though they no longer put on an apron of leaves as their real ordinary garment, wear it over a cotton skirt on festival-days. Among the amusements of a people, songs are often interesting musically, and it is well to take them down, not only for the tunes but also for the words, which sometimes throw light on old traditions and beliefs. Dancing varies from spontaneous expression of emotion to complex figures handed down by tradition and forming part of social and religious ceremony. The number of popular games in the world is smaller than would be supposed. When really attractive they may be adopted from one people to another till they make their way round the world. Any special variety, as of ball or draughts, should therefore be noticed, as it may furnish evidence of intercourse by which it may have come from some distant nation.

Though the subjects of anthropological interest are not even fully enumerated in the present chapter, some idea may have been given of the field of observation still open to travellers, not only in remote countries, but even in Europe. In taking notes, the explorer may be recommended not to be afraid of tedious minuteness, whereas the lively superficiality of popular books of travel makes them almost worthless for anthropology.*

QUERIES ON ANTHROPOLOGY.—*By* A. W. FRANKS, C.B., F.R.S.

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I. *Physical Character.*

Average height of men and women in each tribe.
Woolliness of hair.
Prognathism.
Strength in lifting and carrying weights, &c.

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* More extended accounts of the departments of the Science of Man here noticed, and a list of works useful to advanced students, will be found in Tylor's 'Anthropology: an Introduction to the Study of Man and Civilisation' (Macmillan and Co., 2nd ed., 1889). [EDITORS.]

Speed in running.
Accuracy of aim.
Knowledge of numbers, weights, and measures.

II. *Mode of Subsistence.*

Whether mainly by hunting, or by pastoral or agricultural pursuits. Any instances of dwellings in caves.

Use of boats; forms of boats and of paddles; mode of paddling.

Any particular stratagems used in hunting, snares and traps; implements for hunting; use of dogs and of cross-bows, as well as bows and arrows.

Fishing: nets; fish-hooks; spears; any javelins or arrows with loose heads attached by a cord.

Modes of cooking, and implements used; any particular observances in cooking or at meals; any separation of sexes at meals. How is fire produced? and are any persons charged with the preservation of it?

Forms and construction of houses. Separation of the sexes.

Furniture of houses.

Plans of towns and fortifications.

Plants cultivated for food or manufactures; agricultural implements.

III. *Religion and Customs.*

What are the idols and their names? Is there any distinction between them in importance? What worship is paid to them? and what offerings are made, and on what occasions?

Are there any particular superstitions? What fetishes or amulets are used? by whom are they made? Are there any forms of divination, any use of casting lots with cowries, ordeals by poison or otherwise?

Cannibalism, and motives for the same.

Funeral rites. Belief in a future state. Deposit of objects with the dead, and whether deposited broken or whole, in or on the graves.

IV. *Arts and Manufactures.*

Mode of spinning and weaving; patterns and materials employed.

Dyeing and nature of dyes.

Any mode of preparing and working leather.

Any knowledge of glass-making. If not acquainted with the manufacture of glass, do they melt down broken European glass and beads to make armlets and other ornaments?

Musical instruments: their forms, nature, and names.

Knowledge of pottery and mode of manufacture.

Use and manufacture of tobacco and other narcotics; forms of tobacco-pipes: any ceremonies connected with smoking; use of snuff; snuff-bottles.

Manufacture and trade in salt, wine, beer, or other liquors.

Knowledge of simples and medical remedies, cupping, &c.

Ivory and wood-carving.

Metallurgy: working in the various metals, whether by a special class of people or tribes; implements used in smelting, &c. Where are the ores obtained?

Is there any knowledge of precious stones?

V. *Personal Ornaments, Disfigurements, &c.*

Are there any special marks made by tattooing or cicatrices to distinguish the various tribes? are they the same in both sexes? Drawings of these marks would be very desirable, distinguishing each tribe.

Are the teeth filed or knocked out? If the former, into what shapes are they filed? when is the filing effected? and is it the same for both sexes?

Is antimony used for the eyelids? and how is it applied?

Are ear-ornaments worn by either sex? are they pendent or inserted in the lobe? Are there any nose or lip ornaments?

Is the hair cut into any peculiar shape, or is its colour altered by dyeing?

Is any cap or protection worn on the penis, as by the Kafirs and other tribes?

Any peculiarities of dress for men and women? any distinction between married and unmarried?

What protection is worn in battle? What are the forms of the weapons? and is any missile weapon in use?

Are any marks used as distinctions for bravery, success in hunting or rank?

VI. *Ivory and Wood Carving.*

If elephant ivory is not of native origin, where is it obtained? Are any other materials of the same nature employed in carving, such as walrus-tusk, cachalot teeth, &c.? Are any very hard woods employed; and if so, how are they worked?

VII. *Money.*

What kinds of money are in use? Do the coins pass by weight as bullion, or have they a recognised value? Are any objects such as iron bars or tools, salt, pieces of cotton, cowries, beads, wampum, &c., employed as a means of exchange? If so employed, is there any recognised way in which their value is certified, or is their value the subject of bargain in each case?

VIII. *Miscellaneous.*

Any knowledge of the stars and constellations?

What games are in use? and how are they played?

Are any ancient stone implements found among the natives? and have they any superstitious regard for them?

Are any peculiar ornaments used in dancing?

Are there any modes of marking property?

Are wooden pillows in use? and do their forms differ according to tribes?

It may be added that the native names will in all cases be very desirable.

ETHNOLOGICAL QUESTIONS.—*By* J. G. FRAZER.

(*Supplementary to those of* MR. TYLOR *and* MR. FRANKS.)

1. Are the tribes, clans, or families named after common objects, as animals or plants? Note down all such names. Have the tribes, clans, &c., any special beliefs or superstitions regarding the things whose names they bear? *e.g.*, if they are named after an animal, may they eat this animal? May persons of the same name marry or have sexual connection

with each other? if not, why not? Note all cases of forbidden foods, with the reasons assigned for the prohibitions.

2. Any ceremonies before the setting out or after the return of a hunting, fishing, or war party? Do the hunters, fishers, or warriors perform any ceremonies, or observe any special rules as to diet, sleeping, using certain words, &c., while they are hunting, &c.? Are the persons left at home bound to observe any special rules during the absence of the hunters, fishers, or warriors? Is a man who has killed an enemy or any large game obliged to perform certain ceremonies, or to observe a special regimen for a time? Are men obliged to abstain from women at these times (war, hunting, &c.), or at any other times? if so, why?

3. Any superstitious observances at cutting down trees, building houses, clearing land for cultivation, turning up the soil (by hoeing or ploughing), sowing, ripening of the crops, and harvest? Any rules as to eating the new corn, rice, yams, &c.? Any ceremonies for the making of rain or of fine weather? If land is held in common, how is the produce distributed?

4. Any system of taboo? Who can impose a taboo? and for what purposes? Is it used to protect property? What is the effect of breaking a taboo?

5. Any periodic festivals, as at the solstices, equinoxes, or New Year? Is the beginning of the New Year determined by any agricultural season, as harvest or sowing? Any period of general licence and lawlessness at the New Year, or at any other time? Any periodical expulsion of evil (ghosts, demons, &c.)? any general atonement or purification of the district or village at certain times, as the New Year? Anything in the nature of a scapegoat (human or animal) at the New Year, or any other time? Any periodic extinction of fire and solemn kindling of a new or sacred fire? Is the fire formally extinguished on other occasions, as after a death, during a drought, &c.? Is it kept as a rule perpetually burning, and is its accidental extinction unlucky?

6. Has each person a guardian spirit, patron object, or fetish (animal, plant, stone, &c.), with which he believes that his life is bound up? How is such a guardian spirit or fetish acquired? How is it treated in ordinary life and on special occasions, as sickness, war, &c. What is the exact relation between it and the man? and between it and the totem (sacred animal, plant, &c.) of the tribe or clan?

7. Are kings and chiefs supposed to be endowed with supernatural powers, as the power of making rain and sunshine, causing the crops to grow, &c.? Are they put to death for failing to exert these powers, or for any other reason? Have they to observe any peculiar rules of life?

Hints on Anthropology.—*By* H. H. Johnston.

I do not know that I can add any observations of interest to the admirable *résumé* of the study of anthropology contributed by Mr. E. B. Tylor to this manual, but I may offer a few practical suggestions to travellers intending to visit savage countries which may be of use to them, and which are based on my own practical experience of the difficulty in dealing with the untutored savage.

There is no more fascinating study than the psychology and physical condition of races which belong to other varieties of man than our own; with differences in mental and bodily constitution which, but for their variability, would be almost specific in character. Indeed, were it not that there are so many gradations between the Arab and Negro, or the Dravidian and Australian, judged by our fashion of dealing with other mammalian forms, the Negro or Australian (but that their connecting links with the white men and the yellow are still existing) would be as much or more entitled to be constituted separate species of the genus *Homo* as the chimpanzee, the bald ape, and the gorilla are reckoned as distinct and different species of the genus *Anthropopithecus*. Consequently, while the educated man of science finds his mind broadened and refreshed by contemplating other races whose schemes of morality and social economy are based on widely different premises to his own, and whose physical organisation is, in common with the race's psychological condition, often admirably adapted to the nature of their surroundings and the exigencies of their mode of life, while he will study without prejudice the different phases of humanity in the different quarters of the globe with the same dispassionate interest with which he would regard the forms of life evolved under totally different conditions in another planetary body, the inexperienced European is too apt to approach the study of anthropology full of the prejudices with which his European mode of thought has been

surrounded. He forgets that the duty of an observer is to collect facts without bias, and not to give us his own partial opinion of them. And because these practices are inconvenient or inexpedient in our own civilised condition of existence, that is no reason why he should neglect to describe them, or qualify them as "nasty," "indecent," horrible," "absurd," or "wicked," when he encounters them among the tenets of alien races. He should remember that to the scientific mind nothing is common or unclean, nor is one organ less decent than another. It is the duty of every civilised traveller in countries newly opened up to research, to collect facts, plain unvarnished facts, for the information of those leading minds of the age who, by dint of great experience, can ably generalise from the details contributed from diverse sources.

Europeans, who are among the first to penetrate little known, little exploited lands, inhabited by races totally differing from our own, have often failed to rightly exercise the great privilege which fate has conferred on them, by not securing a precise knowledge of the strange people with whom they come into contact for the first time. Facts gathered under these conditions may be invaluable and irreplaceable. But under all conditions of examining into the characteristics of an alien race of men, the traveller should present himself before them with a perfectly open mind. He should not seal up the timid confidence of the savage, and check—perhaps fatally—the outpouring of what might be of the greatest interest to the scientific student of humanity, by deriding or condemning such and such a custom, according as it may appear ridiculous or reprehensible to his own prejudiced views; nor need he unnecessarily offend the natives by informing them that they are ape-like, or indecently naked, or preposterously clothed, or endowed with an offensive odour. He should remember that he himself may appear to them equally hideous, and may resemble a devil in their eyes, just as they resemble apes in his; that they think his clothing unnatural and unhealthy, when they themselves can live so comfortably and cleanly, with nothing to cover their own glossy, well-oiled skins, and he ought to be able to recognise that the peculiar smell proceeding from his own body which, to his own olfactory sense, does not exist, is painfully unpleasant in their savage nostrils.

In collecting facts about anthropology, whatever you do, avoid vagueness. It is better to describe one custom, one style of architecture, one

individual's body, one religious ceremony with minuteness, even to the neglect of everything else (from the want of time), than to lay before us on your return a series of vague general remarks that the scientific anthropologist will toss aside in disdain. Where you can obtain precise body measurements, as according to the rules laid down in the various manuals of anthropology, such will prove of the greatest interest and value.

Always photograph, if you can, in preference to drawing. A really careful drawing is of course as good as a photograph, but it will not be received by scientific men with the same amount of trust in its authenticity as a photograph; moreover, to make a study of a man's face or body that shall be as correct as a photograph, you must have had a preliminary education in drawing, which few explorers have ever had the leisure to undergo. Still, where it is impossible to use photography or accurate anthropometric instruments, rough sketches or measurements are not to be despised. They will, at any rate, serve to give some idea of the race you have encountered. You will probably find that savage races have the very strongest objection to be measured, and in such cases it is better to abandon the idea altogether until you have resided long amongst them. The same remark applies to both painting and photography. All these practices must be gradually introduced to the native mind, and not sprung upon it with alarming abruptness.

If possible, your photographs of groups and individuals should be taken instantaneously, and without deliberate posing, which will never represent your subjects in their natural aspect. You should watch your opportunity with some one of the many handy little pocket-cameras now in vogue, and photograph the natives in their most characteristic attitudes and engaged in their customary occupations. As in literary descriptions, so in artistic representation, always avoid generalisation as much as possible, and make careful minute studies of individuals rather than of groups and assemblages of people. Endeavour to get into conversation with the natives as much as possible, either directly, or through interpreters. Encourage them to talk on any subject that interests them, and write down phonetically words and phrases that fall from their mouths. Savages often speak with much more clearness, slowness, and distinctness than we do, and you will find it not very difficult, when you are used to phonetic writing, to report whole conversations pretty much as they are uttered. When you translate these afterwards, with the help of your

interpreter, many curious facts and expressions and ideas will be brought to light which you probably would not have elicited by direct questioning. At the same time, question the natives when they are in a communicative mood. Enquire into all the details of their lives. Take care, as I have said before, not to repel them by any expression of your own opinion of certain facts they may reveal, and you will collect a series of most valuable memoranda on the condition of the uncivilised mind. Endeavour to make your notes like your pictures and photographs. Write down things of interest *as you hear them or see them*, and do not trust more than you can help to the deceptive gloss of memory.

With regard to languages, where there is not time to make a profound study of the forms of speech spoken around you, you may nevertheless collect in a short time data very valuable to philologists. Those who intend to collect vocabularies in the districts they travel through (and all who explore new countries should endeavour to do so), should have these vocabularies printed in pamphlets, with six other blank columns on the page, besides the column of English words, so that among related languages the vocabulary will have a comparative character (words for the same subject being placed side by side) that will enable the student to ascertain the relative degree of relationship between the different dialects at a glance. In compiling the vocabularies, the student should be exceedingly careful as to orthography, and not perpetrate the monstrosities in spelling of which English explorers, down to a quite recent date, have been guilty.

Statistics of Strength, Stature, etc.—*By* Francis Galton, F.R.S.

It is not in the power of a traveller to measure a large number of half-savage natives individually, but it is well within his power to obtain approximate and valuable statistics concerning their stature, strength, keenness of eyesight, speed, accuracy of aim, and much else, by a very simple process. It enables him to calculate with a degree of precision (that only those who are familiar with such experiences would easily credit), not only the usual averages, but also the proportion of the people whose strength, stature, &c., exceeds any value that may be mentioned. The

observations consists of two (or better of three) "pass-tests." The calculations are made by the aid of the subjoined Table I.

The simplest way of explaining the method is to work out an example. Let us suppose that the traveller wishes to ascertain the strength of the race of people he is among, as estimated by the weights that different members of it are able to lift. For this purpose, he must select two (or better, three) heavy objects, such as packages or stones, of such weights that only a few of the natives will fail to lift the one, while many of them will fail to lift the other. He must ascertain the exact weights of these packages at his leisure, either before or after the experiment. Call their weights respectively A and B. Then let him induce adult male natives in crowds to try their strength upon them. He may, to this end, good-humouredly, but discreetly, taunt them with accusations of weakness, and offer small prizes to the strongest. He has lastly to note (1) the number of the men who were submitted to the experiment, (2) the number of those who failed to lift A, and (3) the number of those who failed to lift B. This completes the observations. He must then reduce these figures to percentages, viz., out of every 100 persons n fail to lift A and m fail to lift B.

All the required results can be deduced from these data by the help of Table I., according to the method summarised in Tables II. and III., and explained more fully as follows:—

The data in the first of the examples in Table II., are that 30 per cent. (n) of the natives fail to lift 68 lbs. (A), and that 60 per cent. (m) fail to lift 77 lbs. (B). Call these percentages of $n=30$ and $m=60$ by the name of "grades 30° and 60°" (the reason for doing so is explained in the note at the end of the last paragraph, p. 453). Then look in Table I. for the values a and b corresponding to the grades 30° and 60° respectively; they are $a = -0{\cdot}78$ and $b = +0{\cdot}38$. We have next to find the value of $B-A$ divided by $b-a$. To obtain $B - A$, we subtract 68 from 77, which gives 9 lbs.; to obtain $b-a$, we *add* $+ 0{\cdot}78$ to $+ 0{\cdot}38$, which gives $1{\cdot}16$, because the subtraction of $- 0{\cdot}78$ is the same thing as the addition of $+ 0{\cdot}78$. Then dividing $B - A$ by $b - a$, that is 9 lbs. by $1{\cdot}16$, we obtain $7{\cdot}8$ lbs. This determines the value of Q, which *measures the variability* in strength among the supposed natives, and it enables us to calculate how much the strengths of the men who occupy the various grades, or class places, exceed or fall short of the *median* strength of all of them. (The median, M,

is practically the same as the average, and will be here treated as such.) To do so, we, in any desired case, multiply the tabular values in Table I. by Q. Thus the tabular value corresponding to grade 4° being $-2{\cdot}60$, it follows that the inferiority in lifting power of the men who occupy that grade, below the average power, is $-2{\cdot}60 \times 6$ lbs. $= 15{\cdot}6$ lbs. Lastly, we are able by working backwards, to calculate the average strength of all the men; thus finding, as is shown in Table III., that the strength of the man at grade 30° is $Q \times a = 7{\cdot}8 \times 7{\cdot}8 = 6{\cdot}1$ lbs. (or say 6 lbs.) below the average of all the people, and knowing that the actual strength of that man is 68 lbs., it follows that the average strength of all the men is $68 + 6 = 74$ lbs. Again, as the strength of the man at grade 60° is $Q \times b = 7{\cdot}8 \times 3{\cdot}8 = 3$ lbs. above the average, and knowing that his actual strength is 77 lbs., it follows that the average strength of all the people is $77 - 3 = 74$ lbs. as before.

The second example refers to stature; it is treated in exactly the same way as the first. In the third example of weight, three test values have been used, A, B, and C, and the values of Q and M are calculated independently from the data of A and B, of A and C, and of B and C respectively. It will be observed how nearly these three pairs of results agree together, and that the three determinations of M are identical.

The data used in these examples are not fancifully invented for the purpose, but are selected at hazard from a classified set of actual measurements. The results obtained from them by the help of Table I. are seen to be almost identical with those that had been arrived at by the laborious measurements of very many individuals, after performing the usual and somewhat tedious arithmetic operations. I ought however, to say that the figures given in the examples as referring to strength of lifting, in reality referred to strength of pull with the arm as in drawing a bow, but they serve equally well as an example of the method of working. I had no observations of lifting weights available.

Numerous other topics are suitable for inquiry by this method; among them are—

Keenness of eyesight—by distinguishing objects at different measured distances. The experiment should be made in a full, but not dazzling, light, and on a clear day. The objects may be cleanly cut squares of white paper, say $1\frac{1}{2}$ in. in the side, on a broad black ground. Sometimes the square is to be shown with one of its diagonals in a

vertical line, sometimes with two of its sides vertical, the test being the power of distinguishing between the two positions. The experimenter should stand behind the man who is being tested, and should use an opera-glass. An assistant changes the squares according to his signals. Very little indeed is known with certainty about the relative keenness of eyesight of savages and civilised men, after due allowance has been made for the advantage that the former have in their familiarity with the appearance of distant game, and other common objects in their country. Their power of vision has often been largely exaggerated, especially by short-sighted and spectacled men of science, who have sometimes naively wondered at the superior powers of ordinarily gifted men in distinguishing what their own imperfect eyes were unable to see.

Running—by noting the number of those in a foot-race who pass a mark at a measured distance, on the way to the goal, in three different measured intervals of time.

Accuracy of aim with arrows, spears, gun, sling, woomerang, &c. Here it is necessary to pay separate regard to the horizontal and vertical distances from the bull's-eye.

Distance of throw.

Endurance of fatigue of man and beast, by records of past performances over two or more stages of similar country, but of different lengths.

The traveller should always take the opportunity of ascertaining the grade he occupies among the natives in each respect, according to the same tests that he employs with them. He should therefore let one of the pass-tests be an object that he himself can only just succeed with. The experiments will then teach him at once the proportion of the natives who are his superiors or inferiors in each several faculty. On returning home, he can be carefully tested afresh by approved laboratory methods, and any errors in his own methods of testing the natives can be found out, and the results he arrived at about them can be corrected accordingly.

Very great pains should be taken to ascertain and to specify the class of persons who are submitted to measurement, as an accidental bias in selection with respect to occupation, nourishment, race, age, &c., may have severally large effects upon the results. The group examined for statistical purposes should always be as homogeneous as possible, and it should be a perfectly fair sample of the sort of persons it professes to illustrate.

I.—Table of Deviations.

The Grades of Classification run from 0° to 100°. The Unit of Deviation, called Q, is equal to half the difference between the Measures at the grades of 25° and 75°.

Grades	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	Infinite	−3·45	−3·05	−2·79	−2·60	−2·44	−2·31	−2·19	−2·08	−1·99
10°	−1·90	−1·82	−1·74	−1·67	−1·60	−1·54	−1·47	−1·42	−1·36	−1·30
20°	−1·25	−1·20	−1·15	−1·10	−1·05	−1·00	−0·95	−0·91	−0·86	−0·82
30°	−0·78	−0·74	−0·69	−0·65	−0·61	−0·57	−0·53	−0·49	−0·45	−0·41
40°	−0·38	−0·34	−0·30	−0·26	−0·22	−0·19	−0·15	−0·11	−0·07	−0·04
50°	0·00	+0·04	+0·07	+0·11	+0·15	+0·19	+0·22	+0·26	−0·30	+0·34
60°	+0·38	+0·41	+0·45	+0·49	+0·53	+0·57	+0·61	+0·65	+0·69	+0·74
70°	+0·78	+0·82	+0·86	+0·91	+0·95	+1·00	+1·05	+1·10	+1·15	+1·20
80°	+1·25	+1·30	+1·36	+1·42	+1·47	+1·54	+1·60	+1·67	+1·74	+1·82
90°	+1·90	+1·99	+2·08	+2·19	+2·31	+2·44	+2·60	+2·79	+3·05	+3·45

The Table is to be read thus:—Grade 1°, tabular value = −3·45; grade 10°, tabular value = −1·90; grade 11°, tabular value = −1·82.

II.—Examples of Data.

Adult males.	The lesser test. A	No. per cent. who fail is taken as the No. of the grade in Table I.	Tabular value. *a*	The greater test. B	No. per cent. who fail is taken as the No. of the grade in Table I.	Tabular value. *b*
Strength	68 lbs.	30°	−0·78	77 lbs.	60°	+0·38
Stature	65·8 ins.	20°	−1·25	69·2 ins.	70°	+0·78
Weight .. .. .. (3 tests are used here)	125 lbs.	10°	−1·90	139 lbs.	40°	−0·38
	125 lbs.	10°	−1·90	156 lbs.	80°	+1·25
	139 lbs.	40°	−0·38	156 lbs.	80°	+1·25

III.—Calculations from the above Data compared with Observation.

Adult males.	B−A	$b-a$	$\frac{B-A}{b-a}$ =Q	Q×a	Q×b	A−Qa or B−Qb =M	Observed value of M	Observed value of Q
Strength in lbs. ..	9	1·16	7·8	− 6·1	+3·0	74·1	74·0	7·6
Stature in inches ..	3·4	2·03	1·7	− 2·1	+1·3	67·9	67·9	1·7
Weight in lbs. .. .. Three tests	14	1·52	9·2	−17·5	−3·5	142·5	143	10·1
	31	3·15	9·8	−18·6	+12·3	143·6	143	10·1
	17	1·63	10·4	− 4·0	+13·0	143·0	143	10·1

Mem.: When making the subtractions, regard must be paid to the *plus* and *minus* signs of the tabular values, bearing in mind that the subtraction of a negative value is the same thing as the addition of a positive one.

Note.—Table I. is calculated on the basis of the theoretical law of frequency of error, to which all variables tend to conform. That is to say, the deviations at the several grades are always nearly constant in their proportions among themselves, whatever the scale of the variability may be. Q is a measure of that scale. It is called the "probable error" of any single observation, it being an equal chance that the difference between any single observation, taken at hazard, and the average of all the observations, exceeds or falls short of Q.

The Table may be briefly described as an inverse rendering of the well-known values of the "probability integral," reduced to a scale in which the probable error, and not the modulus, is the unit. It is widely applicable to the measures of variable objects of the same general description. The details of its construction are explained at length in the author's work, *Natural Inheritance* (Macmillan, 1889), where Table I. is also printed. It is impossible to go further into the subject here, except to explain why the number per cent. of those who fail is considered to be equivalent to that of the grade corresponding to a bare success. First suppose the class to consist of 100 men, then, as the grades run from 0° to 100°, the grade of the 1st man lies between 0° and 1°; that of the 20th man between 19° and 20°; and that of the 100th man, between 99° and 100°. Now if the 20th man fails and the 21st man succeeds, the half-way position corresponds to that of bare success, and it coincides with the 20th grade. Next suppose the class to consist of 1000 men, and that the 200th is the last who fails and the 201st the first who succeeds. The grade of the former is 19°·95, and that of the latter is 20°·05; therefore, as before, the grade of bare success is 20°·0.

FINGER-PRINTS. *By* FRANCIS GALTON, F.R.S.

As a means of providing against possible future difficulties connected with identification, an intending traveller might well take the small trouble of having prints made of the bulbs of the fore, middle, and ring fingers of his right hand, to be preserved at home with his photograph. Finger-prints afford a perfectly sure means of personal identification, those of no two persons being so much alike as to be indistinguishable by an expert using a lens, the forks and other minute details in the fine capillary ridges, continuing unchanged throughout life, and remaining after death until effaced by decomposition. A letter of safe conduct enclosing the prints of the person to whom it refers, is an easy safeguard against its use by another whose prints are conspicuously different in their general patterns.

Travellers who follow the usual course of instruction at the Royal Geographical Society may have their prints taken there and preserved. Any printer who understands what is wanted would be able to take them properly, if first instructed to spread the ink over his slab in a *very thin* layer, lest the delicate furrows in the bulb of the finger should be clogged with ink, and blot the impression when the finger is afterwards pressed on paper. Distinctness in the impression is the primary object, and *not* blackness. Good finger-prints are usually brown. There are other but less good ways of taking impressions of the fingers. Thus a person may ink them by lightly touching a pad used for inking office-stamps, and then impressing them on paper. Or a piece of crockery, glass, or smooth metal may be smoked *moderately* over a flame and the finger pressed on the smoked surface and then on paper that has been rendered *slightly* damp and adhesive by gum, weak glue, paste, or even by licking it with the tongue. Casts are not so serviceable as prints. Sealing-wax that has been well and long stirred while aflame and then allowed to cool on the surface, takes beautiful impressions without paining the fingers. A surface of half-dried varnish takes permanent marks. Dough (as used for bread seals) takes faint but fairly legible impressions.

PAPER MOULDING OF MONUMENTS, OR "SQUEEZES."

By A. P. MAUDSLAY.

The paper which I have found to be most suitable for this purpose is a hand-made paper commonly used for wrapping up oranges in Spain when they are packed for export. It can be obtained from Messrs. Batalla, of Cacagente, near Valencia, through the agency of Messrs. H. King & Co., of Cornhill. But good moulds have been made by Mr. Purdon Clarke with native-made paper both in Egypt and India, and a serviceable paper is now made in America, and, at a pinch, newspaper, or almost any paper, will serve to take an impression if sufficient patience is exercised.

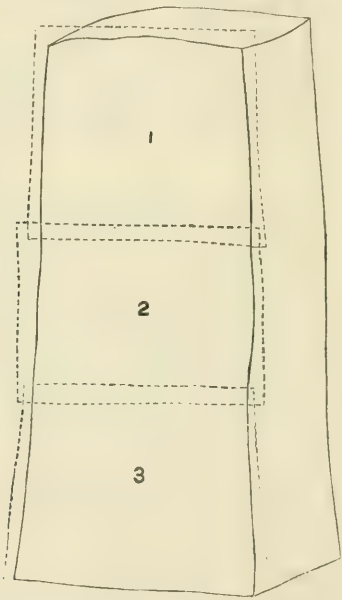
The process of moulding is a very simple one. Soak some sheets of paper in water, and, after wetting the surface of the carving of which you wish to secure a mould, cover it sheet by sheet with the wet paper, beating in each sheet to the form of the carving with a clothes-brush. As the paper will break, and leave portions of the carving bare, this process must be repeated until none of the surface of the carving can be seen. Then give the mould a good coat of paste, and, after waiting a few minutes, lay on more sheets of wet paper, beating them in as before; a second coat of paste is almost always needed, and then beat in more sheets of paper. Leave the mould on the sculpture to dry thoroughly, and, when dry, loosen it round the edges and pull it off. The mould must be made thick enough to keep its shape when dry.

The above is a sufficient description of the process; but the following notes, which are the result of many experiments and considerable experience will be found of use.

Paper can only properly be applied for the purpose of moulding when the carving is free from large contours and deep undercutting; but it is wonderful what accurate results can be obtained even when large curves and some undercutting have to be contended against. Where worn or splintered parts of a wood-carving, or fissures in a stone, or deep undercutting which is not essential to the design, occur, it is often of advantage to fill them up with clay or paper, to which a smooth surface can be given, so that the mould will come away free from them when it is dry;

and careful notes and measurements will often enable one to restore the contour to a mould which has suffered some pressure in transport. In a properly-made mould the detail of carving is never lost, unless the paper itself is destroyed.

A shallow tin bath (or two made to fit inside one another), large enough to hold an open sheet of paper, is useful for soaking the paper in. Twenty sheets or more may be placed in the water at once, and may be

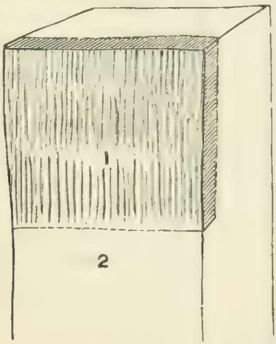


left there without harm for an hour or more; but a few minutes' soaking is quite enough.

I have several times had to mould in America the whole of a monolithic monument—one as much as twenty-five feet in height—covered with carving and hieroglyphic inscription, and have been perfectly successful in reproducing it in plaster in England. Each face would be

marked out into three or more sections, and each section would be moulded separately, great care being taken that each mould should considerably overlap the margin of the other, so that when each section is cast in plaster the edges of the cast can be cut away until the joint is perfect. And each section should also overlap at the top and sides in No. 1, and at the sides in No. 2, &c., for the same reason; and it is necessary to pay careful attention to the beating in of the paper near the sides and edges, as it is there that the layers are most likely to come apart when dry. These edges can be trimmed down afterwards, if found too bulky in packing.

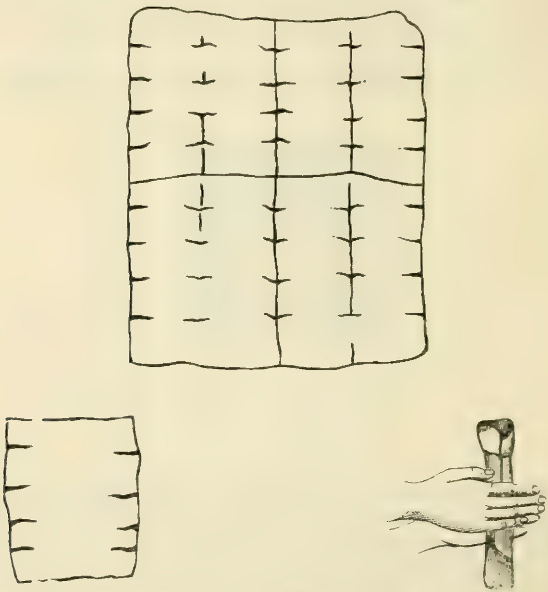
The first sheets of paper should always be put on singly, and well



beaten in. If the carving presents many sharp angles, the paper will again and again be broken away over them, and small scraps of paper may be used for covering them up, until the whole section is covered at least three papers deep in the thinnest place. The coat of paste should then be given. If the paste is laid on when the mould is too thin, it will penetrate to the stone, and prevent the mould coming off when dry. The paste may be put on warm, but if too hot it draws the paper from the stone (if it is a stone sculpture), air gets underneath the paper, and it is very difficult to get rid of it again. Avoid, in putting on the first papers, doubled edges or creases, and beat in well, so that the paper may work into the grain of the stone or wood. It is easy to spoil a mould by

scamping the work on it, but not easy to spoil it by overbeating. After giving a coat of paste with a brush, it is advisable to work in the paste with the fingers, so as to be sure, from the smooth feeling, that it penetrates the paper over the whole surface.

After the first coat of paste has been applied, a good deal of time may be saved by employing an assistant to beat out the paper for the further



thickening of the mould, for when thus beaten out, two or three thicknesses of paper can be laid on at the same time. Take about six sheets together from the water, fold them, and then double them twice, and slightly tear the wet doubled edges, so that when the sheets are laid open again there are a number of small slits in the paper; then lay them out together on any flat surface, and beat them out with a brush for a few

minutes. It is easy to separate them again into the required number of sheets in thickness.

Another method which is equally good, if not better than the last, is, after making the tears in the doubled sheets as before, to unfold them, and then to roll them together and twist them up like a rope, and rub them well between the hands; then unroll them and beat them out for a moment, separating as many sheets as are required. Either of these processes loosens the fibre of the paper, whilst the slits prevent it stretching unevenly. After this treatment it feels to the touch more like wet leather than paper.

As the mould grows thicker the pulpy paper will, from the continual beating, find its way into, and fill up, the deeper cutting; but it should be most carefully watched that the mould is not left too thin over the more prominent parts of the surface, and, with a little practice, the thickness is easily judged by the touch. It is always well to use the fingers frequently both in pressing the paper into its place and working in the paste.

It is difficult to lay down any rule as to the thickness of a mould and the number of coatings of paste necessary. If the mould is of large size, and the carving presents prominent angles or large curves, it may need an average of thirty sheets in thickness to preserve its shape, and three or four coatings of paste; but if the carving is in low-relief on a flat surface, less than half the thickness will suffice.

In hot weather, out of doors, a mould will take about twenty-four hours to dry; but it should be covered up at night from the dew. In damp forests or in bad weather I have dried most of my moulds by building up large wood fires at the distance of a few feet from the sculpture.

It is best to take off a mould when it is cool—in the morning or evening. *Don't be in a hurry about it.*

If the mould is torn or broken in taking it off the carving, mend it with paste *at once.*

When a mould is taken off, lay it to dry in the sun on a flat surface, as there is usually some moisture left in it. If the mould is not flat in shape, support it carefully, so as to preserve the contours.

When the mould is quite dry, it is advisable, but not necessary, to give it, both back and front, one or more coats of boiled linseed oil.

Heat the oil before applying it, and it will then soak in well, and use rather a soft brush, and be careful in oiling the surface of the mould not to rub too hard.

As the paper easily absorbs moisture, the moulds need to be carefully packed. When at work in the forests of Central America, I usually packed several sections of a mould together with tow, crumpled moulding-paper, or other soft packing material between them, and sewed them up in a sort of loosely-woven canvas (known to the sack-makers as "scrims"); these packages were again sewn up in American cloth or other water-proof material, and packed in light crates, for convenience in carriage, and these were exchanged for strong boxes at the port of shipment.

Moulds can be made with an ordinary black bristle clothes-brush; but such brushes wear out very quickly, and it is advisable to be provided with several brushes of different shapes, with convenient curved handles and flexible leather backs.

No explanation is given of the process of casting in plaster from a paper mould, as this would naturally be entrusted to experts in England; but it may be added that a dozen or more casts can be easily taken from a good paper mould without destroying it.

X.

INDUSTRY AND COMMERCE.

By J. S. Keltie, *Assistant Secretary, R.G.S.*

The kind of information desired under this heading may be summed up in the three following questions, so far as uncivilised or semi-civilised countries are concerned:—

(1.) What are the available resources of the country that may be turned to industrial or commercial account?

(2.) What commercial products can find an available market in the country?

(3.) What are the facilities for or hindrances to intercourse between the country and the rest of the world?

Or, briefly, (1) Resources; (2) Wants; (3) Accessibility.

These include the questions of suitability for immigration and colonisation.

What is known as commercial geography is one of several special applications of geographical knowledge. From this practical point of view, therefore, the observations collected under other heads in this book will be of service, especially if the requirements of commerce are kept in view at the same time as the *desiderata* of science. From this standpoint the sections on Meteorology, Geology, Natural History, and Anthropology, should be consulted. Even general geographical and topographical observations will be of practical service—the general lie of the country, its altitudes, and its character at certain altitudes, its mountains, hills, valleys, plains, rivers—if regarded from the special standpoint of habitability and possibilities of development.

The suggestions contained in this, as in the other sections of this manual, are meant both for the ordinary explorer or traveller who may

have to pass rapidly through a country and for those who may have more opportunity for making leisurely observations. To the former the following brief hints may prove serviceable:—

Observe and note—

1. As regards Resources—

The extent or quantity, quality, facilities for raising or collecting, for transport and shipment, &c., of

(*a*) The natural products, such as minerals and metals, especially gold, silver, coal, iron, copper, tin, nitre, guano, phosphates, &c.; timber useful for various purposes; vegetable products, useful for food, fibres, dye-stuffs, or medicine—gums, resins, &c.; animal products useful for food, skins, fur, feathers; riverine or lacustrine products, useful for food, oil, or other purposes.

(*b*) Substances cultivated for food or for manufacturing purposes.

(*c*) Articles manufactured for clothing, for domestic, warlike, or other purposes.

(*d*) Native methods of developing resources, of carrying on manufactures, and of transport.

(*e*) Practicability of developing the resources of the country by European methods.

2. As to Wants:—

(*a*) What particular things used by the natives could be profitably supplied from the outside?

(*b*) What do the natives lack that might be introduced and supplied from the outside?

(*c*) In all cases be particular to note favourite materials, shapes, colours, or other peculiarities, as of cloths, implements, ornaments, such as beads, anklets, &c.

3. As to Accessibility:—

Note the nearest ports and railways; the character and connections of native roads, if any; the navigability of rivers, inlets, and lakes for various kinds of craft at various seasons of the year; heights of passes, whether suitable for animals or

only for porters, whether blocked at any season of year; routes likely to be suitable for railways.

In all cases where practicable, specimens of products should be obtained, in order that specialists at home may judge of their industrial or commercial value.

For those who may have more leisure for observation, some or all of the following detailed hints may be useful:—

Minerals and Metals.—It is not necessary to add much here to what has been said under Geology. If the traveller is not himself competent, or has no opportunity to test the value of these products, he should bring home specimens; this, if possible, should be done in any case. Under this section a look-out should be kept for any indication of naphtha, asphalt, or mineral oils. From the commercial point of view the important points are—

Quality: To what extent are minerals or metals, as gold, copper, iron, phosphates, mixed up with other matter? What is the yield per ton of ore? In the case of coal, how does it burn, and what is the percentage of ash? Next—

Quantity: Does the substance occur in sufficient quantity to make it worth expenditure of capital and labour? The information must be obtained by personal inspection. Finally—

Locality: Is the situation of the deposits easily accessible? How are they situated with reference to routes, existing or practicable? and how with reference to ports of embarkation? Could they be worked with the resources available in the country, or would labour and machinery require to be introduced? If worked in the country, is there any neighbouring market for the manufactured products? What are the native processes (if any) of obtaining and working minerals?

We must again refer to the section on Geology for further details, and the intending traveller would do well to take a few lessons before he leaves, so as to be able to recognise the most common and useful minerals, and the conditions under which they usually occur; he will thus save much time and trouble.

Vegetable Products.—The directions for observation and collection given under the Botanical section should be attended to; and it is

important that the traveller should be able to recognise the chief classes of plants, so that specialists may be able to pronounce generally on their utility.

Character of Surface.—The general character of the surface of a country, so far as its vegetation is concerned, should be clearly grasped. What proportion, or, if possible, what area is under forest? what under grass? what desert, or mountain, or marsh, or uncultivable? what under cultivation?

Forests.—If of a generally forest or thickly-wooded character, are the forests extensive and dense, with much undergrowth, as in tropical South America? or easily penetrable as the forests of Europe and North America? Or are the trees scattered, either in clumps, or singly, as in a great part of Central Africa? Do they prevail over the country generally, or are the river-banks only lined with dense tree vegetation? Are the forests only found in the low country, or do they cover the hills and extend up the mountains?

Timber.—Ascertain the leading characteristics of the trees of the forests. What are the prevailing families, and, if possible, genera and species? What uses, if any, do the natives make of the woods? Which do they use for their houses, their furniture, their canoes, their weapons, their ornaments? How do the woods seem to stand tear and wear, the climate, the attack of destructive insects, immersion in water? Are there any woods that would do for such purposes as railway-sleepers or telegraph-poles in the conditions which prevail in the country? Any ornamental woods suitable for cabinet purposes?

Fibres, Fruits, Chemicals, &c.—Are there any plants the fibres of which could be turned to account? Any fruits adapted to human consumption, and are they found in any quantity, or could they be cultivated?

Are there any trees or other plants suitable for drugs or chemicals—bark, leaves, juices, roots? What medicines, narcotics, or stimulants are used by the natives? how are they obtained and how prepared?

Are there any species of useful plants growing wild—coffee, sugar, cotton, vanilla, spices, &c.? Any trees producing gums that might be of commercial value, like gum arabic, gutta-percha, or caoutchouc? Or any whose fruits yield oil, like the cocoa-nut and the olive? Do the natives make use of these juices? What are the processes of extraction and preparation?

Other Vegetation.—When there is an undergrowth, its character should be noticed, and the diseases, if any, to which trees are subject.

Note what other vegetation exists besides that of trees. Are there any plants like the turnip, the potato, the batata, which are useful as foods, or for other purposes? Specimens of any herbs likely to be useful should be obtained, especially if they are used by the natives for medicine, for dyeing, for poison, or other useful purposes.

Sometimes, as in Central and Western Australia, what arboraceous vegetation exists, consists mainly of shrubs, the character of which should be noted. Do they hinder locomotion? Are their shoots useful for forage? Are they injurious to horses and cattle?

When there is herbaceous vegetation of any extent, what is its character? Is it tall and coarse and reedy, like much of the African grass? Or such as is found on the prairies and pampas? Or of a troublesome spinifex character, as in Australia? Or of a turf-like character, like the grasses of Europe? What are the components of this kind of vegetation, and how far is it likely to prove useful as fodder? What uses do the natives put it to, either for their animals or for manufactures? Do they use it for making mats or cloth? Are there any plants mixed with it injurious to animals? What is the condition of the grass at different seasons of the year? When is it at its best, its strongest, its densest? Is it liable to be parched up at any season? To what extent is its condition affected by the climate, by rainfall, by irrigation, natural or artificial? Is it easily removed, in order to make way for other cultures? Does it spread into the forest region, and has it any special characteristics there? How does it, as well as other useful vegetation, vary with altitude or other local conditions?

Marshes, Deserts, Irrigation.—Note if marshes or peat-bogs, or other special features of the surface exist to any extent, and whether the drainage of marshes is practicable.

Where deserts exist, note their character. Are they sandy, gravelly, rocky, salt? What is the prevailing rock? If the desert character of the land (as is generally the case) seems due to want of water, is there any artificial means likely to be available for supplying that want? Is there any storage of water and irrigation among the natives? and, if so, how is it accomplished? and what are the results? Are there any sources within reach, either above or underground, from whence a supply of

water for irrigation purposes could be obtained? Indicate any exceptional defects of quality in the supply of water.

Note if any part of the country is liable to periodical inundations. At what periods of the year do they occur? Are these inundations destructive, or are they utilised for agricultural purposes? Would it be possible to regulate these inundations?

Agriculture.—The general outcome of all these observations is the suitability of a country for agricultural development. What articles do the natives cultivate, if any? Has the cultivated land any special character, or is it simply the ordinary land cleared of trees or grass, or other wild growth? Note the methods and implements of culture used by the natives; the seasons of sowing and reaping, and preparing the crops for use. Do they depend for water on rainfall or irrigation? To what altitudes is cultivation carried, and what are the crops that prosper at these altitudes?

From the point of view of colonisation and agriculture, precise information as to the nature of the soil is desirable. The proportion or extent of a country suitable for agriculture might be noted. Observe, as precisely as practicable, the nature and depth of the upper layer of soil. The depth—it may be a few inches, or it may be two or three feet—can easily be ascertained. A general idea may also be given of its nature. Is it mostly vegetable mould, as it is likely to be in old forest or grass countries? or peaty? or marshy? If possible, also, ascertain the depth of the subsoil down to the rock or clay, or other permanent basis on which it rests. In a general way it might be observed whether the soil is sandy, gravelly, stony, calcareous, marly, clayey. Also is it compact, tenacious, or loose, and, above all, is it permeable or impermeable to water? Is the soil very dry or very moist? or what is its intermediate stage?

If the natives carry on cultivation, ascertain, if possible, the yield per acre of what they cultivate. Do they cultivate only for their own wants? If not, where and what is the nature of the market to which they send the surplus?

Does the country seem suitable for other cultures besides those carried on by the natives?

Animal Products.—If there are wild animals in the country, observe whether the natives hunt them for what they yield in the way of food or

other useful products. Are there any ivory-yielding animals, or animals whose skins can be turned to profitable account? Could a sufficient supply for mercantile purposes be obtained by means of native hunters, if properly encouraged; or how would it be best to work such resources? Are there any laws or customs enforced by the natives in hunting wild animals? Are there any noxious wild animals, and to what extent do they affect human comfort and human life?

Domestic Animals.—It is important to know what domestic animals the natives possess, how they are reared and fed, and what uses they are put to. Also whether the country is good for horses, cattle, sheep, and poultry, and approximately what is the extent, situation, and accessibility of the grazing-lands. Are the pastures perennial? To what extent do they depend on rainfall, or irrigation, or on intermittent streams? During what months of the year are they available? Are there any plants among the pastures injurious to animals? Are there any insects (like the *tsetse*) or other animals injurious to cattle or horses? Do horses or asses exist among the natives, and what uses are they put to? If not, would they be likely to flourish, if introduced?

Fisheries.—Information concerning fish and fisheries is desirable; and among fish, from the practical standpoint, are included shell-fish (especially pearl shells), sponges, corals, and animals of the whale and seal kind. If the natives practise fishing, either in lakes, rivers, or the sea, ascertain the kinds of fish they capture, their methods and implements, and the particular seasons at which fishing is practised. Are the fisheries, whether worked by the natives or not, likely to be of commercial value?

Trade.—Much of the information suggested above will be of service from the special commercial point of view, especially with reference to export. Information should be obtained concerning any manufactures carried on by the natives besides what has been suggested above—manufactures in metal, in wood, in clay, or stone; in materials derived from the vegetable and animal kingdoms, what they are, what uses they are put to, what processes are used, and to what extent, if any, they form articles of trade. With regard to the import market, what generally are the wants of the natives and what new wants might be created? If possible, some approximate estimate of the value of the leading classes of imports, if there are any, should be obtained.

Ascertain if any goods are brought into the country from the outside; if so, what they are, where they come from, and as accurate an estimate as possible of quantity, or value, or both. In the case of imports from civilised countries, are those of any particular country preferred, and, if so, why? Is it owing to anything special in quality, or pattern, or cost, means of communication, or in quantity available? Is there any special tribe of middlemen who prevent the inland people from coming into direct relation with traders? Probably a market could be created for outside manufactures which have not as yet been introduced into the country; or such manufactures might easily obtain a market in preference to those of native make. Note especially the patterns of articles of native make, as these are probably adapted to the conditions of the country, and should therefore be imitated or improved upon in the case of imported goods, the quality of the latter being better, and the cost, if possible, lower. Note also whether European methods might not be introduced with advantage for the manufacture of native goods.

Climate.—This is an essential item, so far as the exploitation of tropical and semi-tropical countries by Europeans is concerned. Its main elements are determined by temperature, latitude, altitude, and rainfall; the character of the surface should also be taken into account. Under Meteorology, the main directions on the subject are given. The temperature at different seasons and at different times of the day (say 9 A.M., 3 P.M., and 9 P.M.) should be ascertained, and that at various altitudes. Rainfall observations are not of much service unless they can be obtained over a continuous series of years. Ascertain the distribution of rainfall over the year, and the limits of the rainy period of the year, when such period exists, and, if possible, the quantity which falls in the different months of the period; how does the rainfall differ with altitude and other topographical variations? If a country is subject to droughts, it is important to ascertain if there is any periodicity in these droughts, and how they affect the resources and prospects of the country, and the condition of the rivers. Would it be possible by storage of water, or other means, to counteract to any extent the bad effects of drought?

What effect has the rainy period and the drought period on the native inhabitants, and especially on Europeans? As far as possible, ascertain the birth and death rate per annum.

FACILITIES AND HINDRANCES TO COMMERCIAL DEVELOPMENT.—Under this head the first consideration is Accessibility or Means of Communication. Generally, the quickest, cheapest, and safest routes to a satisfactory market should be ascertained.

Water Communication.—Observe what natural means of communication exist, what is the nature of communication between the country and the outside world. If communication by sea is of importance, how is the interior to be reached from the sea? Are there any deep inlets? Is there practicable river communication? For what sort of vessels is it adapted? Are there any obstructions in the river, and, if so, what is their nature, and how could they be surmounted? What is the width of the river, the depth of the water, and the force of the current, at various distances from the mouth, and at the periods of the year when the river is at its lowest and highest? Are there any lakes that could be utilised for communication?

Roads.—If there are native roads, state precisely what is their nature under various conditions of weather; their width; what sort of vehicles, if any, they are suited for, and where they lead to. If the country is mountainous, ascertain the principal passes, what places they connect, their exact heights at the highest point (not the heights of the mountains), for what animals or vehicles they are practicable, or if only for porters, and what is their condition at various seasons of the year. If the natives have any vehicles, or vessels, or other means of transport, describe them.

Railway Routes.—Observe, as far as possible, suitable routes for railway or canal communication, as well as for good roads, and whether any materials for railway construction are obtainable in the country. Possibly the country, if an inland one, could be connected by road or rail with some existing railway system. What are the nearest telegraph stations?

Labour.—Another important consideration under this head is that of labour—labour for the varied enterprises connected with the development of a country's resources. Is labour obtainable within the country itself? If so, to what extent, and on what terms? Are the natives industrious, and are they likely to labour under foreign superintendence? Does slavery or forced labour in any form exist? If not obtainable in the country, how may it be most easily and cheaply obtained? Is the country suited to manual labour by whites? If there are only certain kinds of labour in which whites may engage, state what they are.

To what extent could machinery be used with advantage? Is there any water power available? or any animal power?

Currency, Tariffs, &c.—Under this head also questions relating to currency should be included, or whatever other medium of exchange exists.

Another important consideration here is the question of tariffs, which, in one shape or another, exist in nearly all uncivilised and semi-civilised countries, from the hongo of Central Africa to the Customs duties of Eastern countries. Precise information concerning these, both as to exports and imports, is important.

Note, also, as precisely as practicable, the cost of living for Europeans settling down for a time, and the expenses involved in travelling through a country.

Inhabitants.—Is there anything in the character of the natives—physical, mental, or moral—likely to affect commercial intercourse or the industrial development of the country? Any prejudices or superstitions that should be attended to? Anything in the attitude of natives to traders and settlers deserving consideration? Is the population nomadic or settled? What material, if any, do they use for smoking, and what is the nature of their intoxicating drinks, if they have any? Estimate, as nearly as possible, the population, the density per square mile, both for the country as a whole and for the chief centres of population. Ascertain the nature of any political or social organisation which exists. What are the terms on which land can be acquired? What are the prevalent crimes? Under the Anthropological section directions are given for ascertaining the leading racial characteristics of the people.

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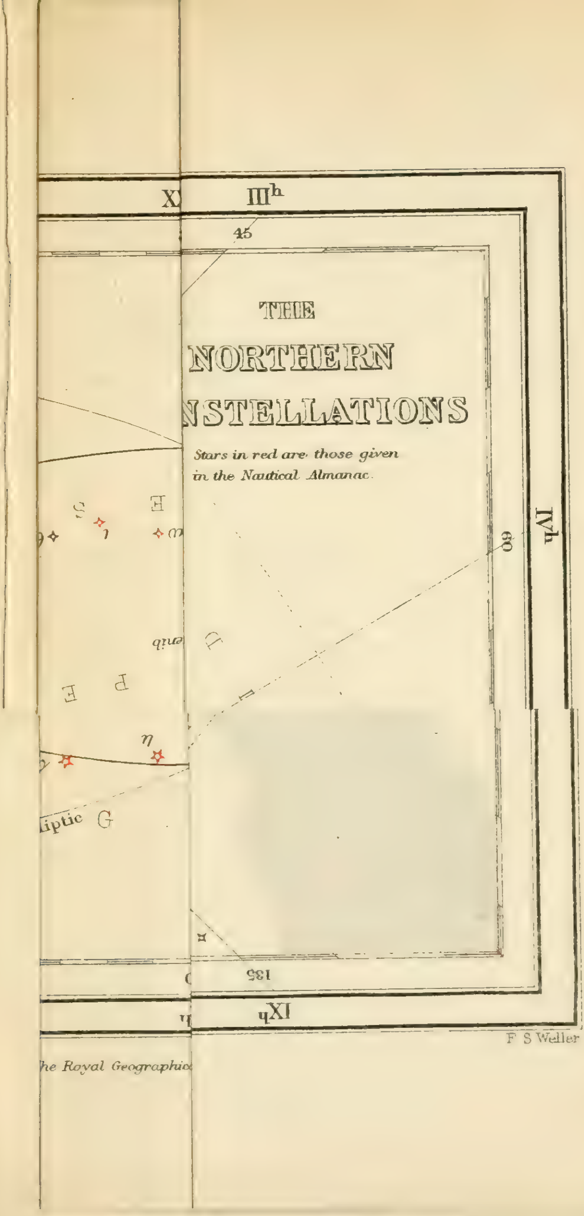
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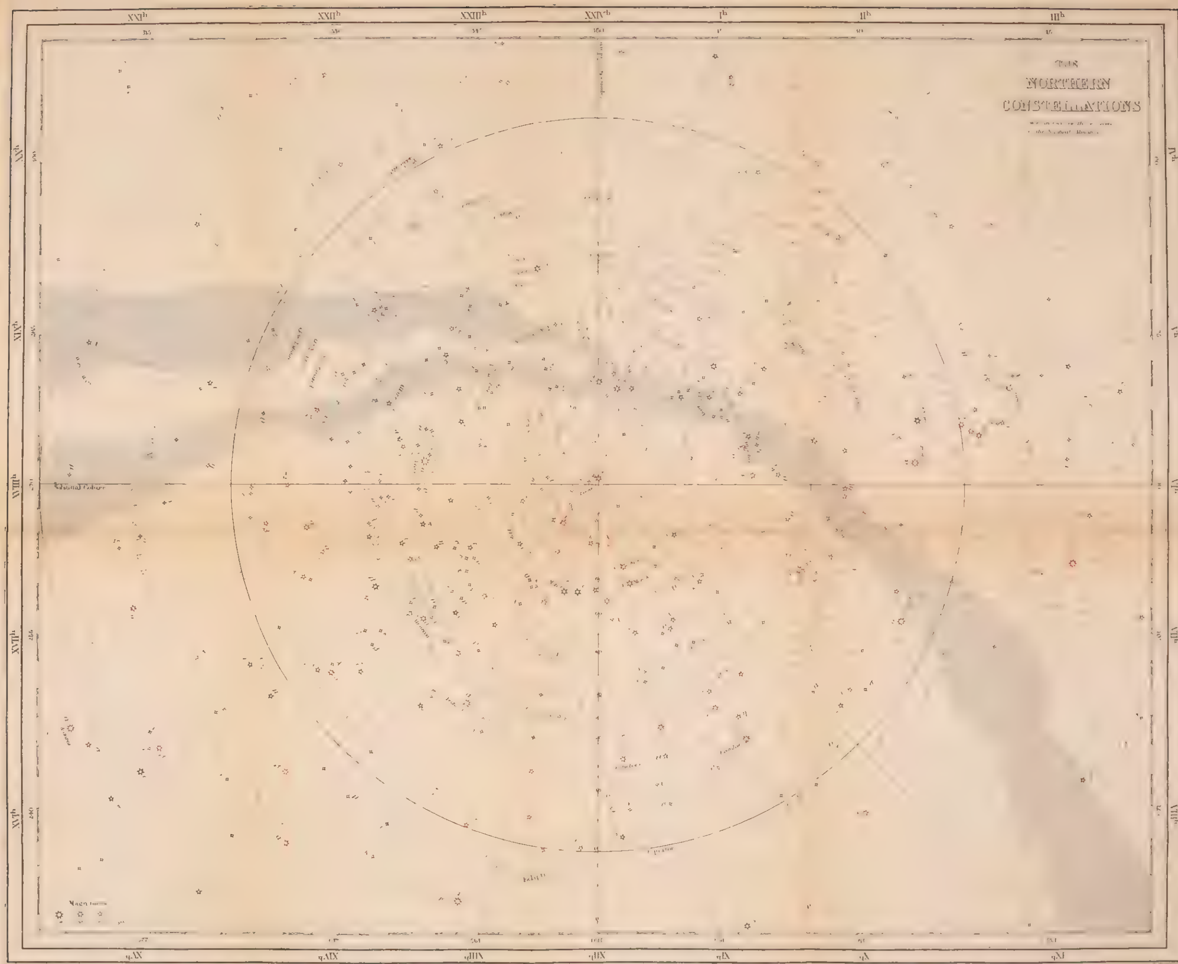

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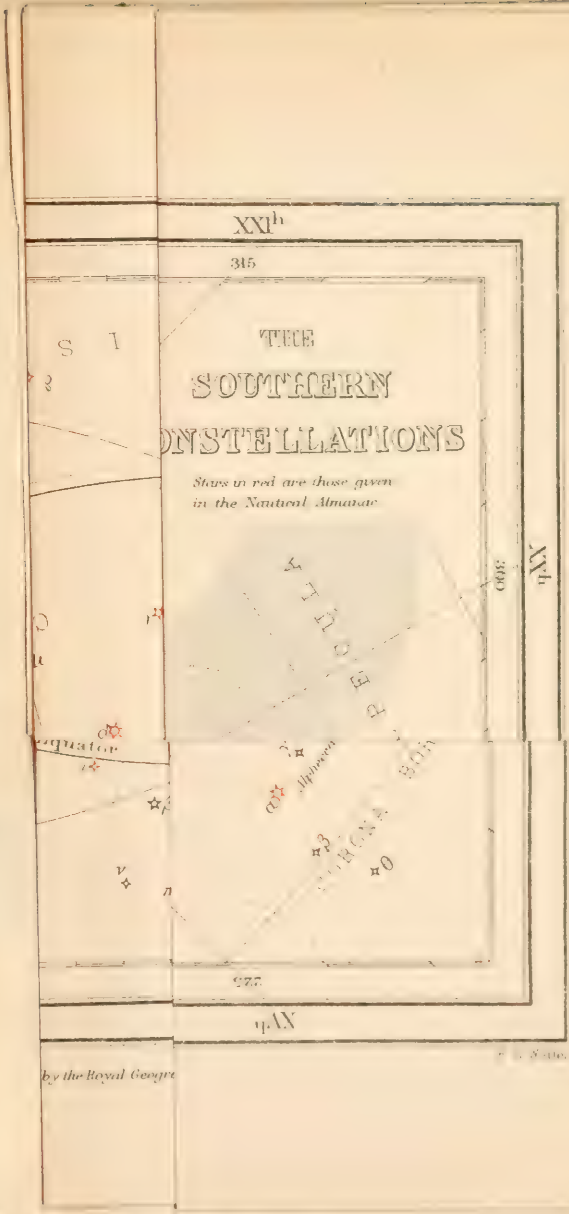

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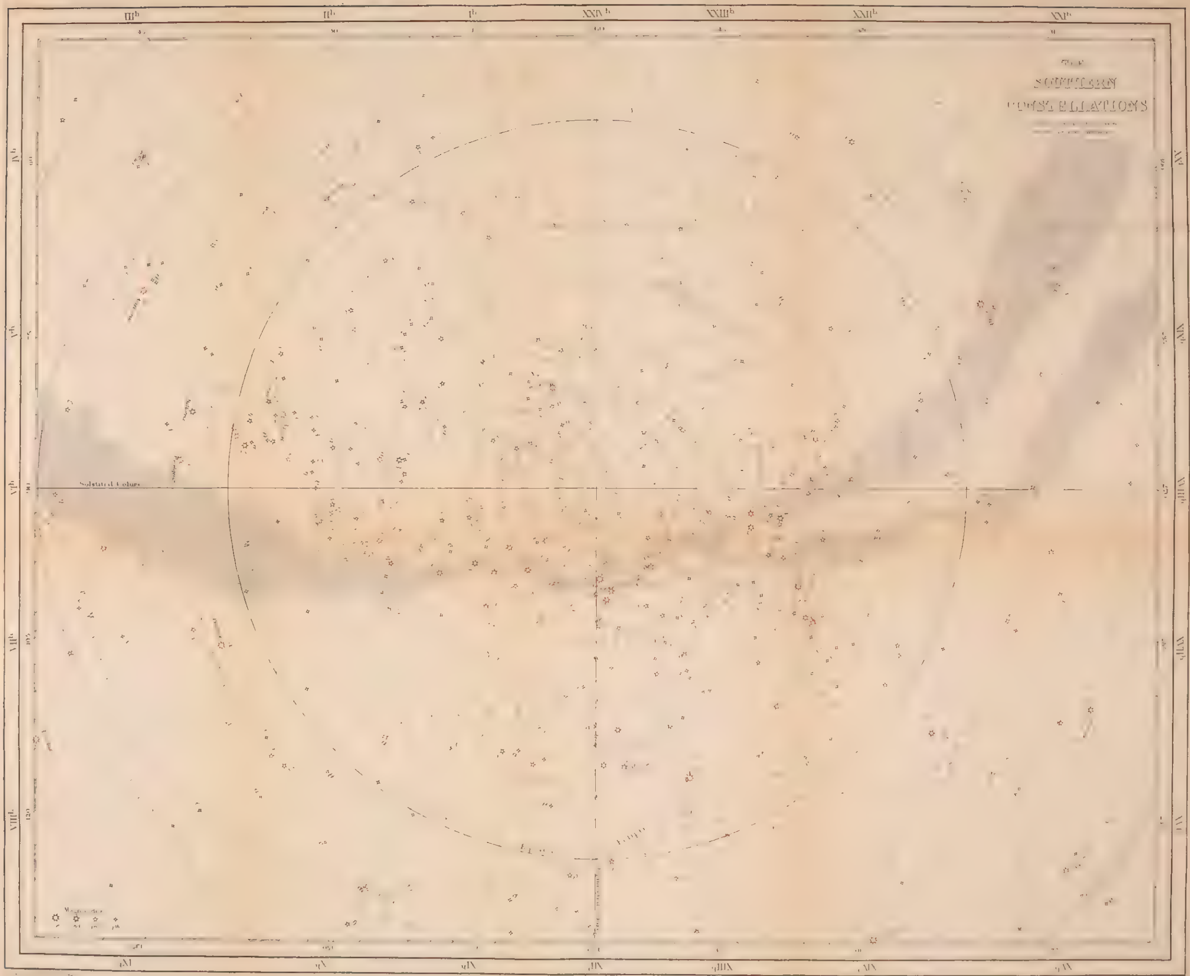
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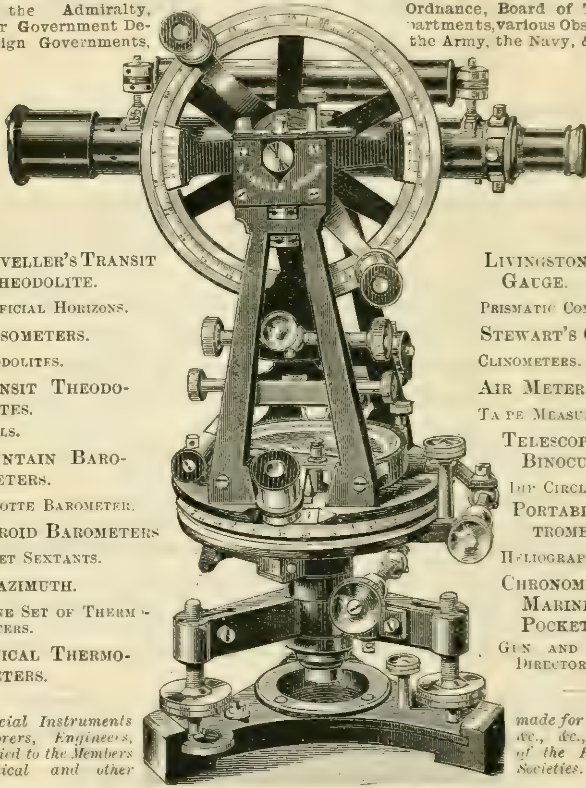

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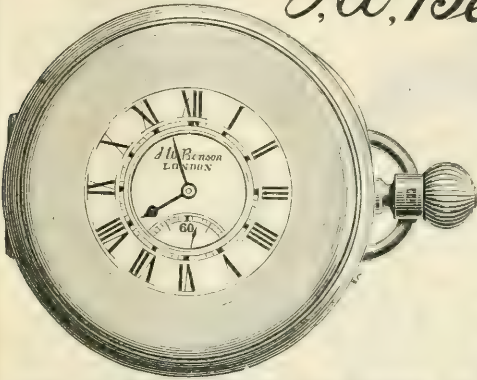

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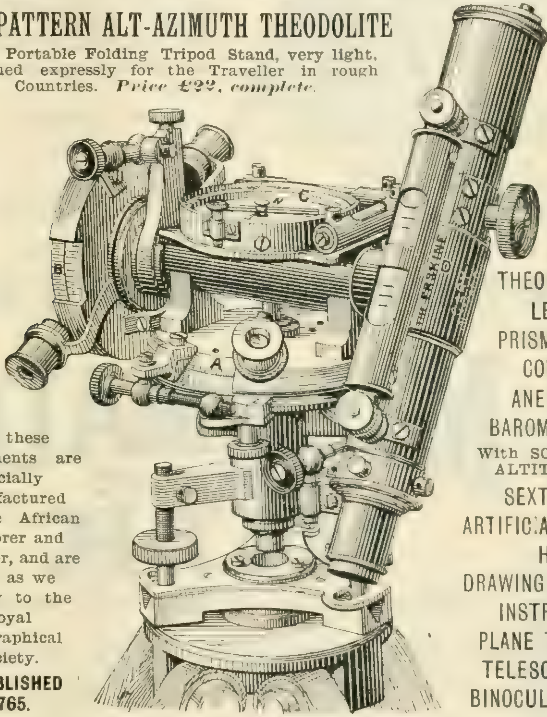

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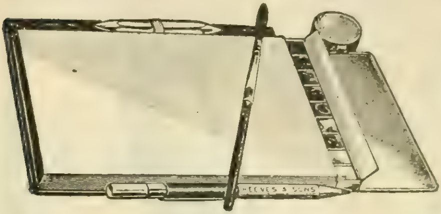

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